JOURNAL OF THE SMPTE

321 Signposts for the Future • *Barton Kreuzer*

322 Letter to Editor — 16mm Projector Possibilities • *Jose M. Ruiz*

323 The Transistor • *R. D. Middlebrook*

330 The Role of Transistors • *Richard B. Hurley*

332 Progress With Transistors • *Burton R. Lester*

334 A Transistorized Seven-Position Portable Mixer • *Kurt Singer*

338 Automatic Recarboning of Carbon-Arc Lamps • *J. P. Latil*

340 Procedures Used to Compare Theater Screens • *Yorick G. Hurd*

347 Minimizing the Effects of Ambient Light on Image Reproduction • *G. L. Beers*

355 A Color Schlieren System for High-Speed Photography • *George E. Hays*

357 Analysis of High-Speed Motion-Picture Data • *William G. Hyzer*

361 Improved 16mm Projector for Research • *S. A. Weinberg, J. S. Watson and G. H. Ramsey*

82d SMPTE Convention • October 4–9 • Sheraton Hotel, Philadelphia

volume 66 • number 6 **JUNE 1957**

JOURNAL of the SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

PUBLICATION OFFICE TWENTIETH AND NORTHAMPTON STREETS, EASTON, PA.

Officers

President, 1957–58
BARTON KREUZER, Radio Corporation of America, Bldg. 2–4, Front & Cooper Sts., Camden 2, N.J.

Executive Vice-President, 1957–58
NORWOOD L. SIMMONS, Eastman Kodak Co., 6706 Santa Monica Blvd., Hollywood 38, Calif.

Past President, 1957–58
JOHN G. FRAYNE, Westrex Corp., 6601 Romaine St., Hollywood 38, Calif.

Engineering Vice-President, 1956–57
AXEL JENSEN, Bell Telephone Laboratories, Murray Hill, N.J.

Editorial Vice-President, 1957–58
GLENN E. MATTHEWS, Research Lab., Kodak Park, Eastman Kodak Co., Rochester 4, N.Y.

Financial Vice-President, 1956–57
JOHN W. SERVIES, National Theatre Supply, 92 Gold St., New York 38, N.Y.

Convention Vice-President, 1957–58
G. CARLETON HUNT, General Film Labs., 1546 N. Argyle Ave., Hollywood 28, Calif.

Sections Vice-President, 1956–57
ETHAN M. STIFLE, Eastman Kodak Co., 342 Madison Ave., New York 17, N.Y.

Secretary, 1957–58
WILTON R. HOLM, E. I. du Pont de Nemours & Co., Parlin, N.J.

Treasurer, 1956–57
GEORGE W. COLBURN, Geo. W. Colburn Laboratory, Inc., 164 N. Wacker Dr., Chicago 6, Ill.

Governors, 1957–58
HOWARD A. CHINN, CBS Television, 485 Madison Ave., New York 22, N.Y.
GERALD G. GRAHAM, National Film Board of Canada, 247 Place Benoit, St. Laurent, P.Q., Canada
UB IWERKS, 4500 Mary Ellen Ave., Sherman Oaks, Calif.
W. WALLACE LOZIER, National Carbon Research Labs., Box 6087, Cleveland 1, Ohio
EDWIN W. TEMPLIN, Westrex Corp., 6601 Romaine St., Hollywood 38, Calif.
JAMES L. WASSELL, 927 Harvard Lane, Wilmette, Ill.

Governors, 1956–57
FRANK N. GILLETTE, General Precision Laboratory, Inc., 63 Bedford Rd., Pleasantville, N.Y.
LORIN D. GRIGNON, Twentieth Century-Fox Film Corp., Los Angeles, Calif.
RALPH E. LOVELL, National Broadcasting Co., 2554 Prosser Ave., W. Los Angeles 64, Calif.
GARLAND C. MISENER, Capital Film Laboratories, Inc., 1905 Fairview Ave., NE, Washington 2, D.C.
RICHARD O. PAINTER, General Motors Proving Ground, Milford, Mich.
REID H. RAY, Reid H. Ray Film Industries, Inc., 2269 Ford Parkway, St. Paul 1, Minn.

Governors and Section Chairmen, 1957
JOHN W. DU VALL, E. I. du Pont de Nemours & Co., 7051 Santa Monica Blvd., Hollywood 38, Calif.
GEORGE H. GORDON, Eastman Kodak Co., 342 Madison Ave., New York 17, N.Y.
KENNETH M. MASON, Eastman Kodak Co., 130 E. Randolph Dr., Chicago 1, Ill.

Section Chairmen
R. A. ISBERG, Ampex Corp., 860 Charter, Redwood City, Calif.
BRUCE S. JAMIESON, 6521 Danbury Lane, Dallas, Texas
WALTER I. KISNER, 123 Browncroft Blvd., Rochester 9, N.Y.
KEITH B. LEWIS, Eastman Kodak Co., 444 Shoreham Bldg., Washington 5, D.C.
CHARLES W. WOOD, Eastman Kodak Co., 4729 Miller Dr., Chamblee, Ga.

Editorial Office

55 West 42d St., New York 36, New York

Editor—VICTOR H. ALLEN

Advertising Manager—DENIS A. COURTNEY

BOARD OF EDITORS

Chairman—PIERRE MERTZ
463 West St., New York 14, New York

HARLAN L. BAUMBACH
D. MAX BEARD
GERALD M. BEST
GEORGE R. CRANE
HAROLD E. EDGERTON
CARLOS H. ELMER
CHARLES R. FORDYCE
LLOYD T. GOLDSMITH
LORIN D. GRIGNON
A. M. GUNDELFINGER
CHARLES W. HANDLEY
RUSSELL C. HOLSLAG
CLYDE R. KEITH
W. I. KISNER
RALPH E. LOVELL
C. DAVID MILLER
JOHN A. NORLING
HERBERT W. PANGBORN
BERNARD D. PLAKUN
ALLAN L. SOREM
R. T. VAN NIMAN
JOHN H. WADDELL
DEANE R. WHITE
W. T. WINTRINGHAM
CHARLES W. WYCKOFF
EMERSON YORKE

Papers Committee Chairman

BERNARD D. PLAKUN, 63 Bedford Rd., Pleasantville, N.Y.

Subscriptions to nonmembers, $12.50 a year; single copies, $2.00 for one-part issues, $2.50 for special two-part issues. A 10% discount is allowed to individual members and accredited agencies on orders for subscriptions and single copies. A list of priced and gratis publications is available. Order from the Society's Headquarters Office, 55 West 42nd St., New York 36.

THE SOCIETY is the growth of over forty years of achievement and leadership. Its members are engineers and technicians skilled in every branch of motion-picture film production and use, in television, and in the many related arts and sciences. Through the Society they are able to contribute effectively to the technical advance of their industry. The Society was founded in 1916 as the Society of Motion Picture Engineers and was renamed in 1950.

Membership in Sustaining, Active, Associate or Student grades is open to any interested person according to his qualifications. Information about membership, technical activities and standards and test films for the industry is available from Society Headquarters.

SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

Headquarters Office: 55 West 42d St., New York 36, N.Y. Cables: Somopict Telephone: LOngacre 5-0172

Executive Secretary: CHARLES S. STODTER

Entered as second-class matter January 15, 1930, at the Post Office at Easton, Pa., under the Act of March 3, 1879, and published monthly.

Copyright, 1957, by the Society of Motion Picture and Television Engineers, Inc. Permission to republish Journal text material must be obtained in writing from the Society's Headquarters Office, 55 West 42d St., New York 36. The Society is not responsible for statements of contributors.

Printed by Mack Printing Company, Easton, Pa.

Journal of the Society of Motion Picture and Television Engineers

VOLUME 66 • NUMBER 6 • JUNE 1957

Signposts for the Future

By BARTON KREUZER, *SMPTE President*

AT EACH convention it is customary to report briefly on the progress of our Society since we last met, to pause a moment to consider our present position, and perhaps to peer at our future as best we can.

As you may know, our Society, due in great measure to the fine efforts of Jack Du Vall and his Membership Committee last year, and of Ed Warnecke and his Committee this year, now numbers almost 6000 members. Of sustaining members, there are now 117. Today the Society consists of nine sections — one more than when we met last, as we extend a hearty hand of welcome to our newest Section, the Canadian Section.

The attainments of our papers and program chairmen are demonstrated by the large program (reported in the news pages of this *Journal*).

The growth of our Society and the expansion of its interests have kept pace with the growth of the industries of which its members are a part and which it serves. Here are a few signposts in the direction in which we are going:

Feature film production this year, although below previous peak levels, will be about 10% greater than last year. Gross admissions to theaters last year showed an increase of $19 million over the previous year. Some of this was due to the change in the admissions tax, but attendance actually increased to an estimated total of 2.2 billion admissions.

For the many years of my connection with the theater business, I remember hearing the total number of theaters in the U.S. described as 17,000 to 18,000 theaters. At the start of 1957, there were just over 19,000 theaters. In 1945, there were 820 of what was then considered an oddity, the "drive-in" theater. This group has now swelled to almost 4500.

From a postwar start, television stations now number about 500. These, in turn, have created the enormous programming demand of television — a demand that is causing $90 million to be allocated to telefilm production this year.

Only a little further ahead on our way is closed-circuit television, which has three principal branches. One of these branches represents medical installations, such as the wonderful closed-circuit color television installation to be visited at the Walter Reed Army Medical Center. A second branch represents commercial usage, such as the now familiar multi-city sales meetings. The third branch is the highly important educational closed-circuit systems. One of the best examples is the well-known Hagerstown, Md., project only 60 miles from here. Sponsored by the Radio Electronic and Television Manufacturers Association, the Ford Foundation, the local Board of Education and equipment manufacturers, that system has 3-cable links between two high schools, six elementary schools, a library, a museum and a Board of Education studio building. In two years it will be extended to link all 48 schools in Washington County by 6-channel cable.

Closed-circuit television, this year possibly a $10 to $15 million dollar business, will by 1962, by some predictions amount to $100 million per year; and of much greater importance, it offers great promise of benefiting the youth of our nation.

There is also the public educational television program which is providing five series of live 13-week programs. These are transmitted through the cooperation of the Ford Foundation to 23 educational stations for public telecast. A filmed series, sponsored in part by the Fund for the Advancement of Education, and prepared by Dr. Harvey Elliott White, Professor of Physics at the University of California, has brought a physics course in 165 half-hour films to 31 high schools in the Pittsburgh area.

Another signpost we see is that of the cable video theater, as some have called it. Possibly at some future Convention, more will be heard on this score.

Just ahead is the signpost marked VTR — video tape recording. We have on the present Convention Program the second substantial group of papers on this subject to be given before our Society. In 1956, it is estimated that usage of magnetic tape amounted to over 7 billion feet of $\frac{1}{4}$ in. tape, chiefly for sound recording purposes. By 1961, it is estimated video tape usage alone, gauged by square feet or area of tape, may account for an increase in tape consumption of 70%.

Another new road is directed towards missile photography instrumentation and further advances in high-speed photography.

Having looked at the present and the nearby signposts for the future, we may examine a few "check points" further on.

We spot such phenomena as increasing replacement of tubes by transistors, the creation of electronic modules for our equipment so tiny that engineers have invented the term micro-miniature to attempt to describe them. We see electronic light amplifiers and increasing automation of more complex, but more reliable, systems integrated at times with computers and data processing apparatus.

Presented at the Get-Together Luncheon on April 29, 1947, at the Society's Convention at Washington, D.C.

Some, who saw at the Institute of Radio Engineers exhibit in New York the tiny TV camera scarcely larger than the "pistol grip" it was held by, have foreseen such lightweight, portable cameras linked to magnetic recording equipment thousands of miles, possibly continents, away, by cable or microwave circuit. The tape-recorded image would provide a motion-picture record for instant viewing or later use. At the same time, any single tape section could be "played back" to provide a "still" picture that could be printed electronically on paper directly from a special type of TV picture tube. Progress will also be made in achieving color prints on paper by such electronic means. Eventually, such systems should become extremely compact since these electronic systems do not have to repeat continuously picture information which is not changing. Thus, more picture "information" can be transmitted and stored in a given area of material.

Obviously, this future we have just been scanning poses problems which can be met only by education. In this field our Society has been active too. For example, this week Ralph Heacock will be holding the first convention meeting of the recently constituted Projectionists Information Committee, which he and his capable subchairmen, Merle Chamberlain and Gio Gagliardi, have been organizing.

As a result in great measure of the efforts of your Past-President, John Frayne, and his Education Committee, the Society is sponsoring courses at several Universities and Colleges in Los Angeles and in New York. Ed Stifle, your Section Vice-President, has also been pioneering. Chiefly through his good efforts, our student section program has been revitalized and there are now student sections at the City College of New York, New York University, Rochester Institute of Technology and the University of Southern California.

Recognizing the key position held by education, not only in the future of the Society and the industries which we serve, but of the nation, your Board of Governors, seeking to promote further this education effort, has authorized an Annual Student's Award to be made first at the next Spring Convention. This Student Award of the SMPTE, a $100 Government Savings Bond, will be awarded annually to the student submitting the best paper at a student section meeting during the preceding school year.

Your Board of Governors is hopeful that this Student Award will be one more factor increasing the interest of students in our industries — to the benefit of student, industry and of our nation.

Letter to the Editor

16mm Projector Possibilities

I have read with great interest the article by John A. Maurer, "Developmental Possibilities in 16mm Projectors," which appeared in the February 1957 issue of the *Journal*. It's true, as stated in Mr. Maurer's article, that the 16mm film medium has reached a high degree of quality to compete with professional 35mm equipment; however, the present 16mm projector is still in a slow developmental process. Several projectors are now selling at high prices without a reasonable approach to the JAN-Spec ideal projector design.

Some projectors now on the market are of first quality with respect to sound reproduction, but fail in mechanical design. The reason is simple: most of the present high-priced 16mm projectors retain the old claw intermittent movement. This is, of course, a polemic point of view for many designers. In Mr. Maurer's article, regarding the mechanical film-drive design, he discussed some interesting points which form the basis of an ideal mechanical design in 16mm projection machines.

Any designer interested in creating a good and efficient 16mm projector must agree that the intermittent sprocket mechanism is the only mechanical means to secure rock-steady projection. The film-drive system must be one with at least 12-tooth feed and holdback sprockets. The main shaft in the intermittent movement must be 1,440 rpm for obvious reasons, and should use worms and worm gears for the rest of the film-drive mechanism, as employed in the Philips EL5000 16mm projector.

Now, for the intermittent movement, there are several good ways of achieving a good acceleration and deceleration pull-down cycle. The use of the old Geneva star, with more than four slots, presents some geometrical difficulties which can be solved by means of elliptical gears or coupled accelerator movements to bring the pulldown cycle under 90° of intermittent shaft rotation. The latter solution seems to be the most rational and is at present employed in some American and European projectors such as the Kodak Model 25 and the Duiker and Leitz 16mm projectors.

However, other designers prefer to use the four-slot Geneva star geared down by means of two gears in 1:2 ratio and coupled to one 8-frame intermittent sprocket. This type of movement is perhaps more complex than one employing a fast-running shaft with a star pinwheel actuated by a single drunken cam. However, the Eugene Bauer Selection II 16mm projector employs the standard four-slot Geneva geared down to one 8-frame intermittent sprocket and is an excellent mechanism. To return to the crossed-shaft intermittent movements, these are at present employed by some manufacturers such as the Holmes Decimittent movement projector, the General Precision Laboratory Model PB100, the Miracle and the Philips EL5000.

If 16mm projectors are designed to compete with the 35mm professional equipment, they must fall into the high-priced field for obvious reasons. The sound-reproduction system with its associated precision film drive—as the optical or magnetic type—presents no difficulty in achieving results comparable to the professional 35mm equipment. Portability is a matter of price and ingenuity in the design. Projectors like the Duiker, Philips, Bauer, Leitz and Hortson are portable and at the same time employ an intermittent sprocket mechanism and professional sound systems, and are, in general, of robust construction.

The film drives in some European machines are simplified as much as possible with respect to the gear train and associated mechanical elements. This condition is found in the Philips machine. The EL5000 projector employs only a worm and three gears for the complete film drive. The use of two mechanically linked synchronous motors, one for the intermittent and another for the film-drive system, is a must in modern operational design. The Kodak Model 25 machine is also a good example of this. The isolation of the intermittent mechanism from the continuous film drive is the best way to assure perfect sound reproduction. The problem of the overall 16mm projector design falls into two categories: the medium priced machine with the claw pulldown movement and relatively good sound reproduction; and the professional-type machine rated as a commercial projector and costing as much as any 35mm theatrical motion-picture equipment.

April 19, 1957

Jose M. Ruiz
P.O. Box 82
Santa Clara, L.V.
Republic of Cuba

The Transistor

By R. D. MIDDLEBROOK

A general qualitative introduction to the semiconductor diode and transistor is presented. The wartime development of the point contact rectifier led to the discovery of the point contact transistor, which was followed by the invention of the junction diode and transistor having many superior properties. The basic physical principles of operation and various commercial devices are discussed. High-frequency effects, and modified forms of the original transistor which improve the high-frequency performance, are described.

IT IS NOT OFTEN that a new scientific advance is brought to public attention in newspapers and popular magazines. When this happens, it is usually because the inventor is already well-known or because the new development promises changes in established consumer applications. It is this second reason which has led to the great public interest in transistors: everyone is familiar with the vacuum tube which is used in radio and television receivers, and the transistor is a new kind of device which can perform many of the functions of the vacuum tube and some new ones in addition. Shortly after the invention of the transistor, the popular press announced that this new device was the successor to the tube and that considerable improvement could be realized in the reduction of power supply requirements and physical size.

Unfortunately, some problems arose in the development of the transistor and although prophecies concerning low power requirements and small size have certainly been vindicated, it has been found that it is not quite so easy to design suitable circuits for use with transistors and, for large scale manufacture, difficulty has been experienced in producing large numbers of units with reasonably similar characteristics. Also, temperature effects are very much more important in transistors than they are in tubes. Although progress has been rather slower than was originally anticipated, the transistor is gaining strength in competition with the vacuum tube and new fields of application are continually being opened up. By describing how the transistor was invented and some of the basic principles fundamental to its operation, this paper will attempt to provide a brief background for those who will use transistors in practical applications. Further information may be found in the references.

Presented on October 12, 1956, at the Society's Convention at Los Angeles, by R. D. Middlebrook, Electrical Engineering Dept., California Inst. of Technology, Pasadena, Calif. Parts of this paper and Figs. 1–9, 18, 21, and 22 are from R. D. Middlebrook's *An Introduction to Junction Transistor Theory*, published this year by John Wiley & Sons, Inc., New York, and are reproduced by the kind permission of the publishers. The author also wishes to thank the appropriate publishers for permission to reproduce certain of the other illustrations. This paper was received on November 14, 1956.

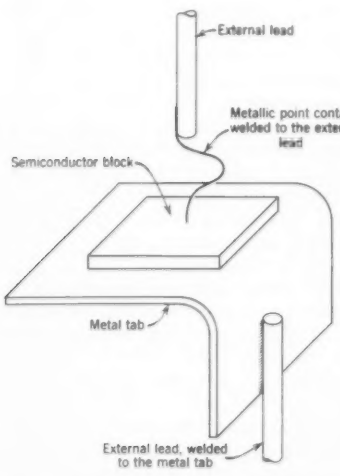

External lead
Metallic point contact, welded to the external lead
Semiconductor block
Metal tab
External lead, welded to the metal tab

Fig. 1. Physical construction of the point contact rectifier.

Crystal Rectifiers

One of the major differences between the transistor and the tube is that the active region of the tube is in a vacuum, whereas the active region of the transistor is in a solid: in particular, in a crystal of semiconductor. As the name implies, a semiconductor is a material which has a conductivity intermediate between that of a conductor and that of an insulator.

The use of crystals in electronics is not new, although some of the older applications used properties rather different from those used in transistors. It is a property of certain crystals that, when twisted or bent, a voltage is produced across the crystal faces: this is called the piezoelectric effect, on which Pierre and Marie Curie, of radium fame, were among the first to work. The particular crystals with which the Curies worked were quartz and Rochelle salt. Modern applications of the piezoelectric effect include the familiar phonograph crystal pickups and ultrasonic radiation devices used in submarine equipment.

At the beginning of the century, crystals found their way into radio in the form of catwhisker detectors. This type of detector consisted of a sharp metallic point pressed onto a crystal of galena (lead sulfide). A detector is merely a rectifier; that is, it allows current to flow easily in one direction and presents a high resistance to current flow in the opposite direction. The early crystal detectors were unreliable devices and fell into disuse with the advent of the vacuum diode. The subsequent enormous development of the vacuum tube caused the crystal rectifier to be almost forgotten until the last war, when it was found that the vacuum diode became unsuitable at the very high frequencies necessary for radar. The principal problem was the large shunt capacitance of the vacuum diode. For this reason, crystal detectors again came into favor because of the much smaller shunt capacitance. A great deal of effort went into the development of crystal diodes, and reliable devices were evolved.[1]

The basic form of these crystal rectifiers, shown in Fig. 1, consists of a metallic point pressed onto a block of germanium, a semiconductor which was found to have the required rectifying properties. The fundamental circuit of the crystal rectifier is shown in Fig. 2, along with that of the vacuum diode for comparison. In either circuit, the rectifier allows current to pass in only one direction and so a d-c component of voltage is established across the load resistance when an a-c signal is applied to the circuit. Although the point contact diode is useful at higher frequencies than the vacuum diode, it is able to handle only small amounts of power because of the small active area.

The Point Contact Transistor

After the war, work on crystal devices was continued in the hope of developing an amplifying device in the same way that the vacuum triode amplifier was developed from the vacuum diode. These efforts were crowned with success at the Bell Telephone Laboratories in 1948, when John Bardeen and Walter Brattain found that a second point contact

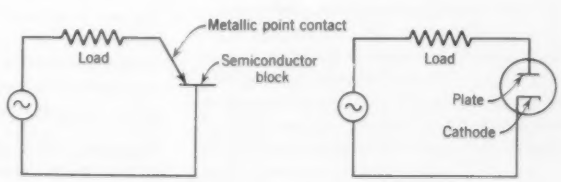


Fig. 2. Basic circuit of the semiconductor rectifier and the vacuum-tube rectifier.

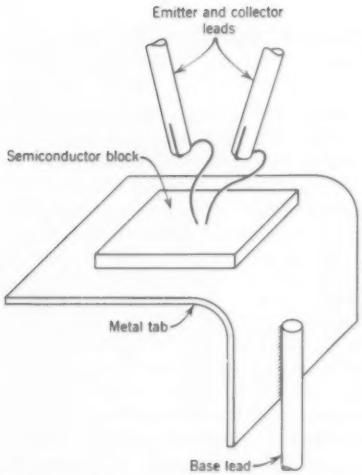


Fig. 3. Physical construction of the point contact transistor.

placed very close to the first on the germanium block would give power gain from the device when it was suitably biased.[2] The basic form of this three-element device is shown in Fig. 3, and the necessary biasing arrangements to provide power gain are shown in Fig. 4. This device was called the *Type A point contact transistor*, the name being derived from the two words transfer-resistor.

In Fig. 4, the diode formed by the lefthand point contact and the germanium block presents a low resistance when the point contact is positive with respect to the germanium, and the current flowing in the lefthand circuit is determined largely by the external series resistance. The germanium block is called the *base*, and the lefthand point contact is called the *emitter* because it emits conventional current into the base when biased in this way. The diode formed by the righthand point contact and the base is biased in the reverse direction when the battery polarity is as shown, and therefore the current expected in the righthand circuit would be small.

If, however, the two contacts are very close together, the righthand contact will tend to collect the current injected by the emitter and is therefore called the *collector*. Thus the current flowing in the collector circuit is controlled by the current flowing in the emitter circuit, and in practice the collector current is from 2 to 10 times the emitter current. The ratio between the collector and the emitter currents is called the *current gain*, *alpha*, of the transistor. It is the linking together of the collector and the emitter circuits which constitutes transistor action, and contact spacing of the order of thousandths of an inch is necessary for this to occur.

The point contact transistor is capable of a-c power gain if an a-c signal source is inserted in series with the emitter forward bias and a load resistance is inserted in series with the collector reverse bias.

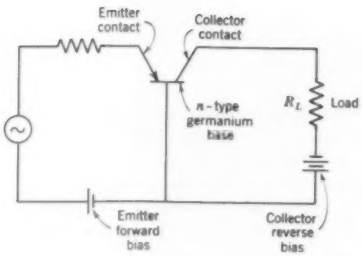


Fig. 4. Bias arrangements to obtain power gain from a point contact transistor.

Power gains of the order of 20 db are readily attainable.[3]

The announcement of the point contact transistor in 1948 opened the way for crystal devices to compete with the vacuum tube in the amplifying field as well as in the rectifying field. The early point contact transistors, however, suffered from several troubles. They were not adequately reproducible; that is, it was not possible to mass-produce large numbers of them with sufficiently similar characteristics, and they were also electrically very noisy. Because of the three-dimensional nature of the device, theoretical analysis is difficult and the internal operation is, in fact, not yet completely understood. Their advantages are ruggedness, small size and low power requirements.

Semiconductor Properties

The development of the point contact transistor might have proceeded more rapidly had it not been for the advent in 1949 of a new kind of transistor invented by William Shockley, also of the Bell Telephone Laboratories. In a classic paper[4] Shockley presented the analysis of a crystal device containing junctions between semiconductors with different properties, each junction taking the place of one point contact. In striking contrast to the point contact transistor, the first junction transistor was not fabricated until some time after the basic theory had been established. The junction transistor has now almost completely replaced the point contact type in most applications.

In order to understand the principles underlying the action of a junction transistor it is necessary to consider crystal structure in more detail.* Presently junction transistors are manufactured from germanium or silicon, both of which are semiconductors at room temperature. Both are tetravalent and exhibit the same crystal structure as diamond. Figure 5 shows this structure in two dimensions at the absolute zero of temperature, in which each straight line represents a valence electron bond between two atoms, and each atom has

* Qualitative treatments of this subject may also be found in Refs. 5 and 6.

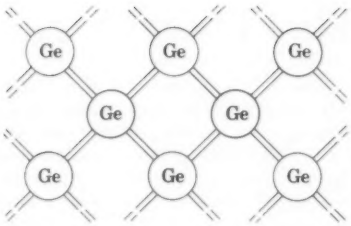


Fig. 5. Pure germanium at zero degrees absolute.

eight valence bonds attached to it. In this condition the material is an insulator because there are no free unattached electrons available for conduction.

At temperatures above absolute zero, thermal agitation causes some valence electrons to gain sufficient energy to break away from the atoms and they are then free to wander about the crystal. Such mobile electrons are capable of carrying current if the random motion has a superimposed average velocity imparted by an electric field. If the number and speed of these mobile electrons are known, it is possible to calculate the conductivity of the material. It is found, however, that the actual conductivity is twice as much as would be expected on this basis. This is because some of the mobile electrons may drop into vacant valence bonds created by thermal agitation: thus the vacancy also appears to move. Every time a mobile electron is produced by thermal agitation, a corresponding vacancy is produced which is also mobile. These mobile vacancies are called *holes*. Although a hole is the absence of an electron, it can for many purposes be considered as a material particle having a positive charge equal in magnitude to that of an electron.

At temperatures above absolute zero, then, mobile electrons and holes are produced in equal numbers, both of which contribute to the conductivity of the material. This situation is depicted in Fig. 6. A material of this kind is called an *intrinsic semiconductor* because the conductivity is intermediate between that of an insulator and that of a conductor, and is a property of the pure crystal. It is apparent that the higher the temperature the more mobile electrons and holes are produced and the higher the conductivity. This is in direct contrast to a metal such as copper, whose conductivity decreases as the temperature rises.

The conductivity of a germanium or silicon crystal may be greatly enhanced by the addition of a trace of an impurity into the crystal. Two different classes of impurity are purposely introduced in this way: elements of valence 5, and those of valence 3. If a small proportion of arsenic or antimony atoms (valence 5) is introduced into molten germanium, the crystal formed on cooling contains arsenic atoms dispersed throughout the

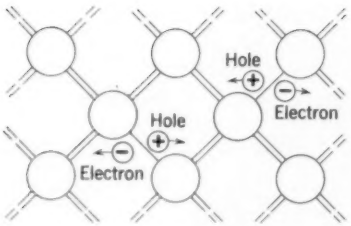


Fig. 6. Pure germanium at room temperature, showing thermal generation of mobile electrons and holes in equal numbers.

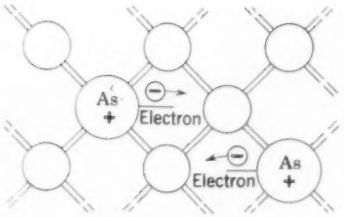


Fig. 7. Germanium with arsenic donor impurity, producing mobile electrons and fixed positive charges.

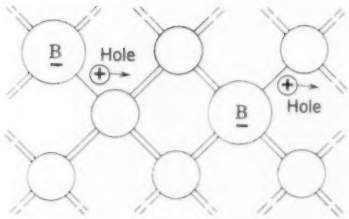


Fig. 8. Germanium with boron acceptor impurity, producing mobile holes and fixed negative charges.

crystal in place of some of the germanium atoms; that is, the arsenic atoms entered by substitution. Each arsenic atom is surrounded by four germanium atoms in the normal configuration, but there is one electron left over. This spare electron becomes detached from the arsenic atom and is free to move about, thus increasing the conductivity of the crystal. Such an impurity is called a *donor*. Since the arsenic atom was originally electrically neutral, when it becomes ionized in this way there is a net positive charge on the atom. Of course, the crystal as a whole remains neutral but the distinction to be made is that the electrons donated by the arsenic are mobile whereas the positive charges are not. Thus a donor impurity produces mobile electrons but does not produce holes. Figure 7 shows this.

An analogous situation occurs when an impurity of valence 3 such as boron is introduced into the crystal. Here the boron atom is short of one valence bond. An electron can be stolen from a neighboring germanium atom and so a mobile hole is created, leaving a fixed negative charge on the boron nucleus (Fig. 8). An impurity of this type is called an *acceptor*.

Mobile carriers produced by impurities far outnumber those produced thermally even for impurity concentrations as low as one part in a million. The predominating type of carrier is called the *majority carrier*, while the other type is called the minority *carrier*. An impurity semiconductor containing donors is called an *n-type semiconductor* (*n* for negative), since the conduction is largely due to electron majority carriers. Similarly, an impurity semiconductor containing acceptors is called a *p-type semiconductor* (*p* for positive), since the conduction is largely due to hole majority carriers.

The p-n Junction

A *p-n* junction is formed when a *p*-type and an *n*-type semiconductor are in intimate contact, and is in thermal equilibrium if no external voltage is applied to it. In this condition the mobile carriers in each region remain at the same densities that they would have if the regions were separate, as shown in Fig. 9.

When a potential difference is applied externally across a *p-n* junction the equilibrium is upset. If the *p*-type region is made positive by a constant amount (as in Fig. 10), mobile holes in the *p*-region diffuse to the *n*-type end while electrons in the *n*-region diffuse to the *p*-type end. Thus there is a net flow of holes across the junction from the *p*-region to the *n*-region, and the equilibrium density of the minority hole carriers in the *n*-region is increased.

As soon as the holes cross the junction, however, they start to recombine with the electron majority carriers in the *n*-region which causes the hole current to fall off exponentially with distance into the *n*-region. A similar action occurs with the electrons flowing the other way: electrons crossing the junction out of the *n*-region start to recombine with hole majority carriers in the *p*-region. It should be noted that the total current crossing the junction is the sum of the injected hole and electron currents crossing the junctions since, although the holes and electrons flow in opposite directions, they also have opposite charge signs and therefore the conventional current is in the direction of the hole flow in each case. The magnitudes of the currents crossing the boundary are determined by (among other things) the applied potential. Since there is a large reserve of majority carriers in each region, a small increase in potential can give rise to a considerable increase in current. Thus when the *p*-region is positive with respect to the *n*-region the device exhibits a low resistance. If the polarity is reversed, as in Fig. 11, holes tend to flow from the *n*-region to the *p*-region and electrons tend to flow from the *p*-region to the *n*-region. However, since holes in the *n*-region are minority carriers and there are very few of them, the hole flow soon reaches a limit as the potential is increased. This occurs when all the available holes are being drawn out of the *p*-region. The electron current saturates in a similar way. Thus when the *p*-region is negative with respect to the *n*-region the device exhibits a high resistance. It is apparent then that the *p-n* junction operates as a rectifier with a characteristic like that shown in Fig. 12. The physical action as described above only occurs if the reverse voltage is not too great. Under these conditions the rectification characteristic is approximately given by

$$I = I_s(e^{40V} - 1)$$

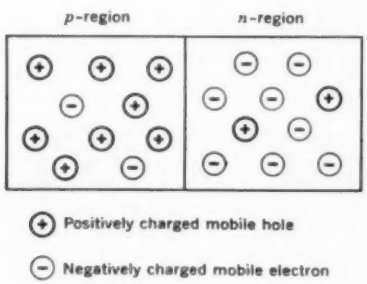


Fig. 9. Mobile carrier distribution in a *p-n* junction in thermal equilibrium. In the *p*-region, holes outnumber electrons; in the *n*-region, electrons outnumber holes.

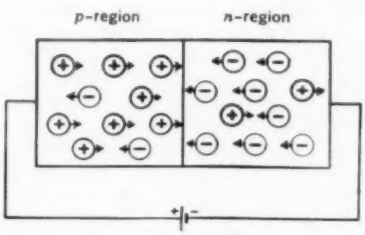


Fig. 10. Mobile carrier flow in a *p-n* junction under forward bias. Majority carrier holes flow from the *p*-region to the *n*-region, and majority carrier electrons flow from the *n*-region to the *p*-region.

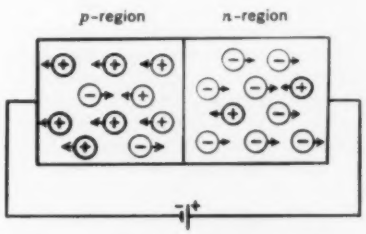


Fig. 11. Mobile carrier distribution in a *p-n* junction under reverse bias. Minority carrier electrons flow from the *p*-region to the *n*-region, and minority carrier holes flow from the *n*-region to the *p*-region.

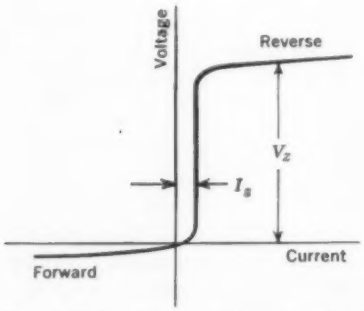


Fig. 12. Voltage–current characteristic of a junction diode.

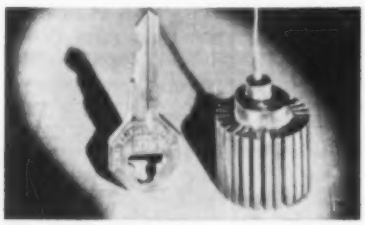


Fig. 13. A Westinghouse silicon power rectifier.

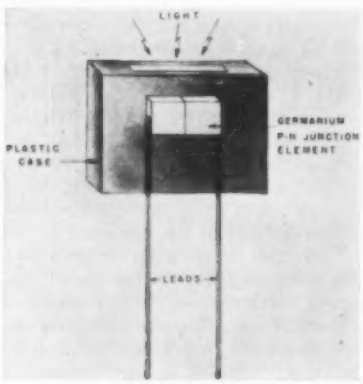


Fig. 14. A cutaway view of a Western Electric photodiode.

in which V is the voltage from the p-region to the n-region, I is the forward current, and I_s is the reverse saturation current.

It is seen that the junction diode is not a perfect switch because there is a small but finite voltage drop in the forward direction and a small but finite current when biased in the reverse direction. Reduction of both of these quantities requires conflicting design criteria, and therefore in practice a compromise must be sought for specific purposes by suitable choice of material and impurity content. Silicon is superior to germanium for high power rectifiers because silicon has a smaller value of reverse saturation current, I_s, and is also able to withstand higher temperatures without losing its properties. A Westinghouse silicon power diode is shown in Fig. 13. This unit is only 1 in. high and 1 in. in diameter, yet has a rectification efficiency of 98% and

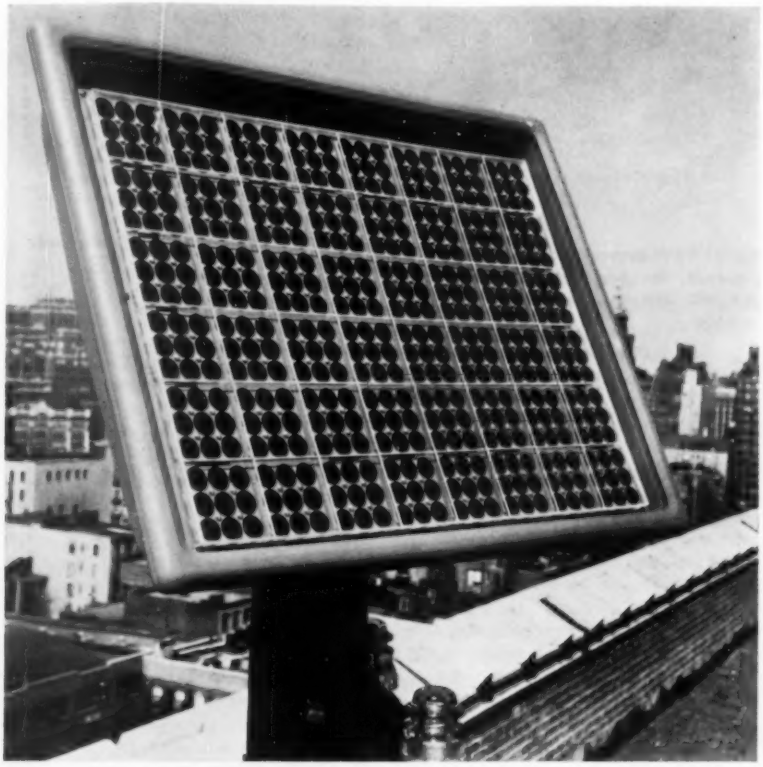


Fig. 15. A Bell Telephone Laboratories Solar Battery.

will provide 1200 w of rectified power with forced air cooling.[7]

The sharp bend shown in the reverse characteristic of Fig. 12 occurs because of an internal breakdown effect. The voltage at which breakdown occurs and the dynamic resistance in the breakdown region can be controlled in manufacture, and this effect is utilized in voltage reference diodes. These reference diodes are similar to the neon tubes used in regulated power supplies, but have the added advantage that a wide choice of breakdown voltage is available.

Another use for p-n junctions is in photoelectric devices. If a junction is exposed to light radiation, extra hole-electron pairs are generated and cause a voltage across the junction which is dependent on the intensity of the incident light. Such a device is shown schematically in Fig. 14. A development of this principle is represented by the solar battery,[8] having a power conversion efficiency of 6% (compared with 1% for the older thermoelectric junction). A modified form of the solar battery (Fig. 15), shown at the World Symposium on Solar Energy at Phoenix, Ariz., in November 1955, contained 400 silicon p-n junctions and gave 0.75 amp at 12 v. The cost of this battery was $10,000, but it is expected the price will fall when manufacturing methods are improved.

The Junction Transistor

Since it has been found that a p-n semiconductor junction has rectification properties similar to those of the point-contact diode, it may be expected that two p-n junctions close together would have power-amplifying properties similar to those discovered for the point contact transistor. This is indeed so, and by extension of the physical principles of the junction diode described above, the principle of the junction transistor can readily be deduced.

Suppose that in the p-n junction in Fig. 10 the n-region is cut off very close to the junction so that few of the injected holes have had time to recombine before reaching this new sawed-off outside edge. Let another p-region now be attached to this new outside edge and a negative potential be applied to it with respect to the n-region, as in Fig. 16. All the holes reaching the second junction will be drawn over into the second p-region because of the negative potential

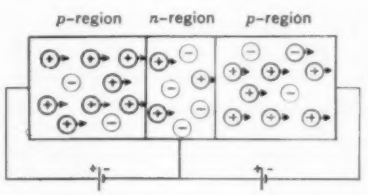


Fig. 16. Mobile carrier flow in a p-n-p transistor under normal bias. Minority carrier holes injected into the base diffuse toward the collector.

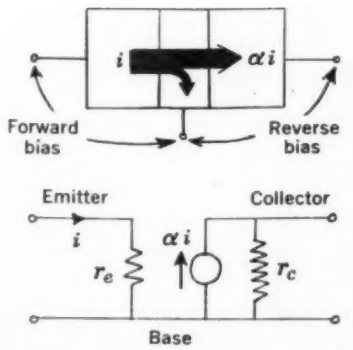


Fig. 17. Above: Input current division between the collector and the base in a junction transistor in the amplifying condition. Below: A simple equivalent circuit for a junction transistor.

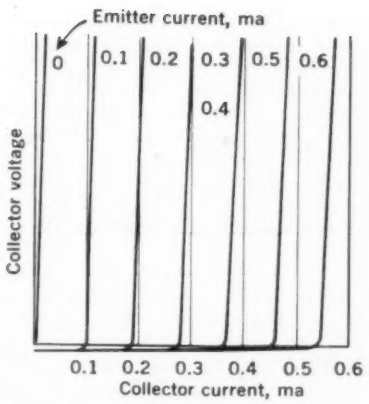


Fig. 18. Collector voltage–current characteristics of a junction transistor.

there. The resulting device is a *p-n-p junction transistor*, and it will be seen that the biasing arrangements are identical to those of the point contact transistor. Two *p-n* junctions take the place of two point contacts and corresponding names are applied to the three regions. The *n*-region in the middle is called the base, the positively biased *p*-region on the left is the emitter, and the negatively biased *p*-region on the right is the collector.

It is the passage of holes through the base region from emitter to collector that constitutes transistor action since the holes provide a link between the emitter input circuit and the collector output circuit. As with the point contact transistor it is necessary that the two junctions should be very close together, in the order of thousandths of an inch, for transistor action to occur effectively. Figure 17 shows the manner in which the hole current flows from the emitter to collector. Some holes will recombine with electrons in the *n*-type base region and the current carried by them will pass out through the base region contact. Again, the ratio of the collector to the emitter current is the current gain alpha, but in junction transistors alpha is always less than 1 at room temperature because of the loss of holes in the base by recombination. Obviously, the thinner the base the fewer the holes which will have time to recombine before reaching the collector junction and the more closely will the current gain approach unity.[9]

A simple equivalent circuit for a junction transistor is also shown in Fig. 17, in which the resistance r_e is low (of the order of 50 ohms) because the emitter junction is forward-biased in the direction of easy current flow, and the resistance r_c is high (of the order of 500,000 ohms) because the collector junction is reverse-biased in the high-resistance direction. The collector characteristics of a junction transistor are shown in Fig. 18, in which it is seen that the collector current is determined by the emitter current and is almost independent of the collector voltage. It will be noticed that these characteristics are very similar in form to the plate characteristics of a vacuum tube pentode, with the important exception that in the pentode the plate current is proportional to grid voltage whereas in the transistor the collector current is proportional to emitter current. This means that the tube is a voltage-operated device whereas the transistor is a current-operated device, and redesign of circuits is necessary in order to substitute transistors for tubes.

Transistors possess many advantages over vacuum tubes in consequence of their comparatively small size and low power consumption. A tube requires perhaps 50 v on the plate to give good linearity, but a transistor will work linearly with a fraction of a volt on the collector. The tube requires about 2 w just to heat the cathode, but the transistor requires no heater. An example of the extremely low power level at which a transistor will operate is shown in Fig. 19. This is a simple oscillator circuit powered by a "wet" cell consisting of a dime and a piece of moistened paper. The output power is sufficient to be clearly audible in headphones.

Another major advantage of transistors is that they exist in two complementary forms, the *p-n-p* type discussed above and the *n-p-n* type shown in Fig. 20. The principle of the *n-p-n* is the same as that of the *p-n-p* transistor except that electrons, instead of holes, crossing the base constitute the link between the collector and the emitter circuits. Because electrons and holes have opposite charge signs, the bias battery polarities are reversed in the *n-p-n* transistor compared with the *p-n-p*. There is no complementary vacuum tube type: there is no tube which operates as an amplifier with a negative potential on the plate. Combinations of *p-n-p* and *n-p-n* transistors make possible new circuit applications and permit simpler realization of established applications.[10]

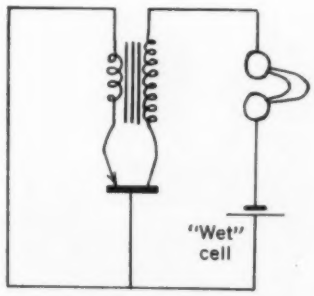


Fig. 19. A simple oscillator circuit using a junction transistor.

Manufacture of Junction Transistors

Although silicon transistors are now available, the early junction transistors made use of germanium as the basic material, and were made by one of two methods. In the first method,[11] usually used for *p-n-p* transistors, small dots of indium (valence 3), an acceptor impurity, are heat-fused into opposite sides of a thin wafer of *n*-type germanium. The recrystallized regions of germanium at the surface of the indium dots contain diffused indium and are therefore converted to *p*-type. Metal wires are then welded to the two indium dots and to the *n*-type germanium wafer, and the unit is encapsulated in plastic or hermetically sealed. A transistor made by this method is called a *fused-junction* or an *alloy-junction transistor*. A photograph of an alloy transistor with the case removed is shown in Fig. 21.

In the second early method of transistor manufacture,[12] usually used for *n-p-n* transistors, a thin *p*-type region is grown into a single *n*-type crystal during the crystal-growing process. After suitable cutting operations, a small bar is ob-

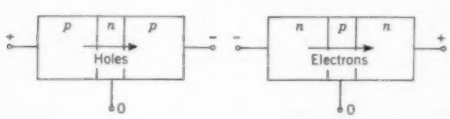


Fig. 20. Complementary types of junction transistor: left, the *p-n-p*; right, the *n-p-n*.

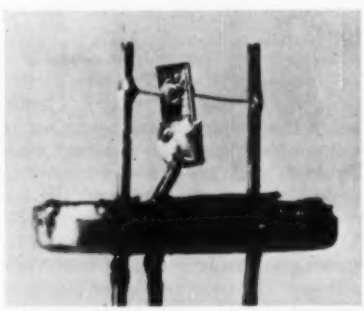


Fig. 21. An uncased alloy-junction transistor.

Fig. 22. An uncased grown-junction transistor.

tained which contains two *p-n* junctions close together. Wires are attached to the two ends of the bar, which become the emitter and collector leads, and a third wire is welded to the thin *p*-type region at the center of the bar to become the base lead. A transistor made by this method is called a *grown-junction transistor*, an uncased unit of which is shown in Fig. 22.

High-Frequency and Feedback Effects

Although there are many advantages to transistors, there are also some disadvantages which must be considered in practical applications. The most important of these disadvantages arise from the frequency limitations and the presence of internal feedback in the device.

An understanding of why there is a frequency limitation can be obtained by reconsideration of the method of carrier flow across the base region. The conductivity of a semiconductor, although higher than that of a vacuum, is nevertheless much lower than that of a conductor. An appreciable voltage drop is therefore necessary in order to support a moderate current. When bias voltages are applied to a transistor, it is found that the potential drops within each region are very small and practically the whole of the applied voltages appear directly across the internal junctions. In particular, the potential drop across the base region is very small, and in fact the resulting electric field in the base region is insufficient to support the observed hole current which crosses the base region from emitter to collector. What, then, is the mechanism by which holes traverse the base?

To consider this problem, imagine a demonstration which shows how current flows in an ordinary electric circuit. Let a channel containing a number of spherical balls in contact with each other represent a section of a wire containing mobile electrons (a conductor). In this model, the application of an electric field to the conductor may be represented by pushing the balls from one end of the channel. The balls then move along the channel *en bloc*, each retaining its relative position with respect to the others. In other words, the *disturbance* caused by pushing from one end propagates almost instantaneously to the other end, although the individual balls move slowly. Correspondingly, in the electric circuit, application of an electric field causes a disturbance to propagate with the speed of light while the individual electrons move very slowly. A current produced in this manner is called a *drift* current, since it results from drift of carriers in an electric field.

There is, however, another way in which "current" can be caused in the channel model. Suppose that at first the channel is empty, and then a number of balls are dropped in at one end. The balls will roll along the channel and spread out, and eventually become evenly distributed along the channel. Notice that this time the disturbance propagates no faster than the balls themselves move along the channel. Notice also that no electric field was applied because the balls were not pushed from one end. The balls do not like to be piled up in one place, and so they spread out by random collisions until they are evenly distributed throughout the available space. It is this second kind of current flow which occurs in the base region of a transistor.

It has already been seen that when the emitter of a *p-n-p* transistor is forward biased, holes are injected into the *n*-type base region. This increases the density of holes at the base near the emitter junction above its original value, and so the holes spread out from the emitter junction in an attempt to equalize the density throughout the base, just as the balls injected at one end of the channel attempt to become evenly distributed. However, as long as the emitter remains forward biased, holes are continuously injected so that the hole-density gradient in the base is maintained. Those holes which reach the collector junction are drawn over into the collector region if the collector-base junction is reverse biased. Current flow by this second method is called *diffusion* current, and occurs whenever there is density gradient of carriers. Both drift and diffusion currents occur in semiconductor devices, but in the junction rectifier and transistor the diffusion currents are the more important.

The frequency response of the junction transistor is determined in part by how long it takes the carriers to make the journey from emitter to collector, since the signal cannot appear in the collector circuit until the carriers reach the collector. If an a-c signal is applied in the emitter circuit and the frequency is

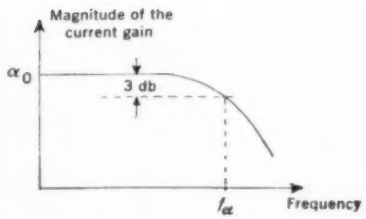


Fig. 23. Magnitude of the current gain as a function of frequency, for a junction transistor.

gradually increased, a frequency will be reached at which the period of the signal is comparable with the transit time of carriers across the base. If the frequency is increased still further, phase cancellation will occur in the collector circuit and the collector current will fall off as the frequency rises even though the input signal remains constant in amplitude. Thus the current gain alpha is constant up to a frequency defined as the *alpha cutoff frequency*, above which it decreases. Figure 23 shows the way in which the magnitude of the current gain varies with frequency. The alpha cutoff frequency of the early junction transistors was on the order of 500 kc although the response of modern types extends into the megacycles.

Another problem which must be taken into account in the application of transistors is the presence of a capacitance across the base-collector junction. This capacitance occurs because of a space charge region at the junction and may have a value between a fraction of a micromicrofarad and about 50 $\mu\mu$f depending on the kind of transistor. Although this capacitance may seem very small, it must be remembered that it shunts the high collector resistance of the order of 500,000 ohms and therefore may cause the current in the external collector circuit to fall off at a quite low frequency.

Another problem arises because the base current, even though it is a small proportion of the emitter current, must flow to the base terminal through the very narrow base region of the order of a few thousandths of an inch thick. The base region may have an appreciable resistance, amounting to several hundred ohms, and thus the voltage appearing at the external base terminal may not be the same as the voltage within the base region. The modifications to the simple equivalent circuit caused by the presence of the collector capacitance and

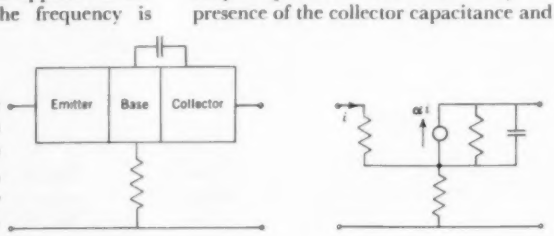


Fig. 24. Addition of the collector capacitance and the base resistance to a junction transistor, together with the modified equivalent circuit.

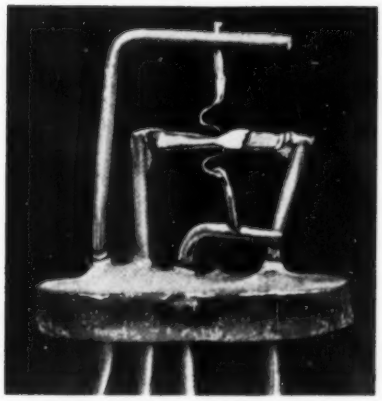


Fig. 25. An uncased Germanium Products tetrode transistor.

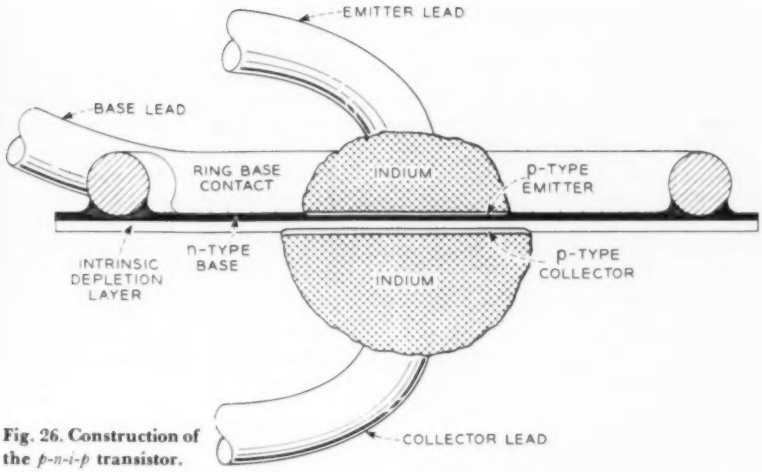


Fig. 26. Construction of the *p-n-i-p* transistor.

the base resistance are shown in Fig. 24. The base resistance is particularly important because it is common to both the emitter and the collector circuits and thus introduces internal feedback in the device. This complicates the design of cascaded amplifier stages because whenever the load of one stage is changed, the input impedance of the same stage is also changed and is reflected back to earlier stages.

Modified Types of Transistor

A certain degree of control over the equivalent circuit element values is possible by suitable choices of the semiconductor materials and physical dimensions. But again, compromises in design are necessary. As an example, a narrow base region is necessary in order to produce a high alpha cutoff frequency because the narrower the base the shorter is the transit time of the carriers; however, a narrower base region also increases the base resistance, which is an undesirable effect. Quite early in the development of the transistor, modified designs were proposed which introduced extra degrees of freedom in the design and thus permitted better compromises to be reached.

One of the first of these modifications was the transistor tetrode,[13] which consisted of a basic grown-junction transistor with the addition of a second base lead on the opposite side of the bar from the original base lead. When a suitable bias current is passed through the second base connection, a transverse electric field is set up across the base forcing the emitter-to-collector current to flow through that part of the base close to the original base lead. This has the effect of reducing the base resistance for a given base width and therefore a given alpha cutoff frequency. A photograph of an uncased Germanium Products tetrode is shown in Fig. 25.

Another modification of the original triode junction transistor structure was proposed by J. M. Early of the Bell Telephone Laboratories. This device is known as the *p-n-i-p* transistor,[14] shown in Fig. 26; it is also feasible in its complementary form, the *n-p-i-n*. The *i* stands for "intrinsic," and refers to a region of semiconductor between the base and collector regions in which there are essentially no impurities. The purpose of the intrinsic region is to widen the space charge layer which occurs at the junction between the base and collector, thus reducing the capacitance across the junction. At the same time, it is possible to reduce the base thickness without reducing the collector breakdown voltage, which in turn leads to higher current gain and higher alpha cutoff frequency. The frequency range of the unit may be extended by an order of magnitude or more above that of the ordinary triode structures, the improvement resulting from the higher alpha cutoff frequency and the lower collector capacitance.

Yet another modification consists in varying the amount of impurities in the base region,[15] the concentration of impurity being greatest near the emitter junction and least near the collector junction. This has the effect of providing a built-in electric field which assists the diffusion flow of carriers across the base region. Again, this results in a higher alpha cutoff frequency. Such devices are called *field effect* or *drift* transistors and their upper frequency limit can be in the hundreds of megacycles.

Conclusions

Improvement in transistor types and methods of application is proceeding at a rapid rate. Many problems have been encountered, but transistors are now well established in many fields, especially those in which miniaturization and low power requirements are of paramount importance. Although transistors may never completely replace vacuum tubes, there are many applications in which transistors can do as well or better than tubes, and others in which tubes cannot even compete. Unfortunately, transistors are inherently more complicated than vacuum tubes, and it is highly desirable that persons charged with the design of equipment utilizing transistors should have at least a qualitative knowledge of the principles of their operation.

References

1. H. C. Torrey and C. A. Whitmer, *Crystal Rectifiers*, vol. 15 of Radiation Laboratory Series, Massachusetts Inst. Technology, McGraw Hill Book Co., 1948.
2. J. Bardeen and W. H. Brattain, "The transistor, a semiconductor triode," *Phys. Rev., 74:* 230, 1948.
3. R. M. Ryder and R. J. Kircher, "Some circuit aspects of the transistor," *Bell Sys. Tech. J., 28:* 367–402, July 1949.
4. W. Shockley, "The theory of *p-n* junctions in semiconductors and *p-n* junction transistors," *Bell Sys. Tech. J., 28:* 435–489, July 1949.
5. G. L. Pearson, "The physics of electronic semiconductors," *Trans. AIEE, 66:* 209–214, 1947.
6. W. Shockley, "Transistor electronics: imperfections, unipolar and analog transistors," *Proc. I.R.E., 40:* 1289–1313, Nov. 1952.
7. E. F. Losco, "Silicon power rectifier handles 1200 watts," *Electronics, 27:* 157–159, Dec. 1954.
8. G. Raisbeck, "The solar battery," *Scientific American, 193:* 102–110, Dec. 1955.
9. F. S. Goucher, G. L. Pearson, M. Sparks, G. K. Teal and W. Shockley, "Theory and experiment for a germanium *p-n* junction," *Phys. Rev., 81:* 637, 1951.
10. G. C. Sziklai, "Symmetrical properties of transistors and their applications," *Proc. I.R.E., 41:* 717–724, June 1953.
11. J. D. Fahnestock, "Production techniques in transistor manufacture," *Electronics, 26:* 131–134, Oct. 1953.
12. F. H. Bower, "Manufacturing grown junction transistors," *Electronics, 27:* 130–134, Dec. 1954.
13. R. L. Wallace, L. G. Schimpf and E. Dickten, "High frequency transistor tetrode," *Electronics, 26:* 112–113, Jan. 1953.
14. J. M. Early, "P-N-I-P and N-P-I-N junction transistor triodes," *Bell Sys. Tech. J., 33:* 517–533, May 1953.
15. H. Kroemer, "The drift transistor," *Naturwissenschaften, 40:* 578, Nov. 1953.

Bibliography of Books

W. Shockley, *Electrons and Holes in Semiconductors*, D. Van Nostrand Co. Inc., New York, 1950.

R. F. Shea, Editor, *Principles of Transistor Circuits*, John Wiley & Sons, Inc., New York, 1953.

R. F. Shea, *Transistor Audio Amplifiers*, John Wiley & Sons, Inc., New York, 1955.
A. Coblenz and H. L. Owens, *Transistors: Theory and Applications*, McGraw-Hill Book Co., Inc., New York, 1955.
A. W. Lo, R. O. Endres, J. Zawels, F. D. Waldhauer and Chung-Chih Cheng, *Transistor Electronics*, Prentice-Hall Inc., New York, 1955.
W. D. Bevitt, *Transistors Handbook*, Prentice-Hall Inc., New York, 1956.
M. S. Kiver, *Transistors in Radio and Television*, McGraw-Hill Book Co., Inc., New York, 1956.
R. D. Middlebrook, *An Introduction to Junction Transistor Theory*, John Wiley & Sons, Inc., New York, 1957.

Editor's Note

Parts of this paper and Figs. 1–9, 21 and 22 are from the author's book, *An Introduction to Junction Transistor Theory*, published early this year by John Wiley & Sons, Inc., and have here been reproduced with the kind permission of the publisher.

In addition, permissions have been granted by Bell Telephone Laboratories, Inc., for the use of Fig. 12 from their book, *Transistor Technology*, p. 281; by *Electronics*, Dec. 1954, p. 157, for Fig. 13; by Western Electric Company for Fig. 14 from Coblenz and Owens' *Transistors: Theory and Application*, McGraw-Hill Book Company, Inc., p. 87; by Bell Telephone Laboratories, Inc., for Fig. 15; by *Radio-Electronics*, Sept. 1955, p. 49, for Fig. 25; and by Bell Telephone Laboratories, Inc., for Fig. 26 from the *Bell System Technical Journal*, May 1954, Fig. 1, p. 520. We wish to acknowledge their kind cooperation.

The Role of Transistors in Electronics

By RICHARD B. HURLEY

The junction transistor and diode with support from saturable magnetic core have deepened the area of study and application in solid state electronics. While transistors are at a disadvantage in temperature sensitivity when compared to tubes, their ruggedness, longevity, lack of heater supply and high circuit efficiency should soon make them the principal active circuit element. Transistors operate on a dual basis analogous to tubes and yet in different modes. As a switch, they are superior to tubes and offer many advantages over electromechanical relays. With saturable cores they compete successfully with certain rotating machines and offer a large class of almost unexplored electronic circuits.

In 1948, after surface studies by Bardeen and Brattain, Dr. William Shockley working with a group at Bell Telephone Laboratories invented the important junction transistor. Practical realization of this invention demanded two important steps. First, a method had to be found to purify a semiconductor element to degrees as high as one part in millions; second, a technique had to be developed for producing perfect single crystals of large dimensions up to several cubic inches.

The purification problem was solved initially by a "zone refining" process in which a crucible of germanium was drawn through a series of induction heating coils. The heat caused the germanium to melt. As the germanium cooled between coils, the forward end cooled first, causing the impurities to drift toward the rear since they preferred the molten state. The monocrystalline problem was solved by a technique of seeding a crucible of molten germanium with a small perfect chunk of crystal. The seed was then slowly withdrawn while temperatures were carefully maintained such that the molten germanium solidified on the seed in a continuous single crystal fashion. With the major obstacles out of the way, the junction class of semiconductor electronic devices became a practical reality.

Presented on October 12, 1956, at the Society's Convention at Los Angeles by Richard B. Hurley, Convair, a Division of General Dynamics Corp., Pomona, Calif.
(This paper was received on August 13, 1956.)

Advantages

The first significant application of the junction transistor was in the hearing aid field. The small size and high efficiency of the junction transistor made it a natural choice as a low-power, compact audio amplifier for hearing aids. Also the initial high cost of transistors was not a serious deterrent in this application compared to the more competitive fields of radio and television. Today all commercially produced hearing aids are completely transistorized.

In the past few years, junction transistors and diodes have made headway in practically every aspect of electronic endeavor in the research and experimental laboratories. Applications past the research phase have appeared in the forms of servo amplifiers, portable radios, car radios, intercom systems, portable measuring instruments and digital computers. Reports on digital computer applications have indicated better than an order of magnitude decrease in power consumption and more than an order of magnitude increase in reliability when converting from tubes to transistors. To evaluate fully the position of transistors, the fundamental advantages and modes of operation, as compared with older devices, should be considered.

State-of-the-art disadvantages of junction transistors compared with tubes include:

1. greater unit cost;
2. lower frequency response (to a few hundred megacycles);
3. lower power dissipation (less than 100 w);
4. less uniformity of characteristics; and
5. fewer types available.

Fundamental disadvantages include:

1. greater temperature sensitivity; and
2. lower impedance levels (can be advantage or disadvantage depending on mode of operation and circuit requirements).

Fundamental advantages include:

1. smaller size;
2. lack of heater;
3. greater circuit efficiency;
4. greater ruggedness;
5. freedom from microphonics;
6. longer life;
7. lower impedance levels (can be advantage or disadvantage); and
8. availability in two polarities (*n-p-n* and *p-n-p*).

Junction diodes compare with vacuum diodes in much the same manner as junction triodes to vacuum triodes. As ordinary diodes and rectifiers, new junction germanium and silicon diodes compete favorably with vacuum diodes, gaseous diodes, and the older semiconductor rectifiers such as selenium. In addition, junction silicon diodes operating in reverse voltage breakdown have shown themselves generally superior to VR tubes and batteries as voltage level changers in

circuits, as voltage reference elements in power supply regulation, and as secondary voltage standards in various types of electronic circuits. Also voltage clamping, usually accomplished with a diode in forward orientation along with a supply voltage, can now be accomplished with a single silicon diode in reverse breakdown (no supply voltage required). In reverse breakdown, the silicon diode may have a better or a poorer internal series resistance and voltage temperature coefficient than a VR tube or a battery. Generally the silicon diode excels in these two items at voltages below about 50 v — particularly in the neighborhood of 5 v for single diodes and in the region of 10 v for two diodes with opposing temperature coefficients. Practically all other considerations decidedly favor the silicon diode. These additional considerations include:

1. smaller size;
2. greater ruggedness;
3. longer life;
4. greater temperature range (compared with batteries);
5. lack of high initial firing voltage requirement (compared with VR tubes);
6. less change in the value of the reference voltage with time; and
7. less noise (compared with VR tubes).

Associated with the high circuit efficiency of junction triodes is the fact that they have a thermally produced built-in "plate" (collector) potential of a few tenths of a volt. Thus they can be "starved" (the "hushed" operation of Volkers and Pedersen) to a point where their noise figure as an audio amplifier may be less than that of low-noise vacuum tubes. Furthermore, in certain low-power applications, they can operate with little or no plate-supply voltage. Even more important is the fact that a junction transistor makes a very good switch. As a synchronized driven switch it sometimes serves better than a diode.

Except for state-of-the-art problems, the transistor as a switch is immensely superior to the tube. It competes very well with the tube in such switching circuits as multivibrators, Schmitt triggers, and blocking oscillators. Because of the junction transistor's excellence as an electronic switch, many electronic functions now performed on a linear or analog basis will become more practical when performed in a switching or digital manner. Thus transistors will compete not only with tubes on a one-to-one basis and perform services in a different and perhaps more satisfactory way but also will make economically feasible jobs tubes were unable to do. Junction transistors as switches have already demonstrated their capabilities of performing functions previously the domain of electromechanical devices.

The grid (base) and the cathode (emitter) terminals of a transistor may be thought of as the terminals of a relay coil. The plate (collector) and cathode (emitter) terminals are then analogous to the contacts of a relay. Considering the junction transistor then as a competitor of an electromechanical relay, the "on" (saturation state) and the "off" (cutoff state) settings are not as good as those of the older device. In low-level applications, however, on-voltage drops below a millivolt and off-leakage currents of less than a microampere are readily obtainable. If the on-off characteristics and power-handling capabilities of available transistors are ample for a particular application, the transistor is favored. Its advantages include:

1. smaller size;
2. greater ruggedness;
3. longer life;
4. higher speeds or frequencies;
5. lack of audible noise and vibration during operation;
6. no contacts to pit; and
7. less phase shift.

When modern high-quality saturable magnetic cores are employed in conjunction with switching transistors, still another new class of circuits evolves. Magnetic amplifiers are enhanced by the advent of high conduction junction diodes, synchronized transistor switches in place of diodes, and junction transistor preamplifiers. The concern here, however, is not with magnetic amplifiers as such, but rather with circuits whose basic properties require a combination of switching transistors and saturable cores for their existence in practical and economical achievement. Commercial magnetically coupled transistor multivibrators employing a pair of power transistor switches and a transformer with square-loop core material have already reached the market. These devices are used for the conversion of low-voltage d-c power to either high-voltage d-c or to a-c. Thus they compete, and favorably, with dynamotors and rotary inverters, with obvious advantages over the more conventional electromechanical rotating machines provided their power and temperature properties make them applicable.

A form of the magnetically coupled multivibrator may be used as an FM modulator for telemetering circuit voltage and current levels. Also many circuits combining switching transistors and saturable cores are being discovered that offer new and novel building blocks for communication, computation and control circuitry.* These circuits include counters, multipliers and dividers, analog-to-digital converters, integrators, modulators and detectors, and polyphase supply systems. These are a new class of circuits hardly exploited.

* See papers on circuits combining switching transistors and saturable cores from *Trans. AIEE*, which appear in *Communication and Electronics*, beginning with the March 1955 issue.

Modes of Operation

The junction transistor is seen entering every major branch of electronics, excluding the extremely high-frequency and high-power segments. Proper perspective of its role may be gleaned from the listing of its modes of operation and application which follows:

1. Linear amplifier (competition with tubes):

a. Analogy. Often the transistor can "directly" replace a tube in a given function if the impedance levels are dropped by a factor of about 100.

b. Duality. If the relative roles of current and voltage are interchanged, a transistor can often replace a tube in an operation. This mode generally shows the transistor in a more advantageous light than in the analogy case since here it is desirable that input impedances be zero instead of infinite. Considering practical impedance levels, a short-circuit input is more nearly obtainable than is an open-circuit input for a transistor.

c. New or physical. Frequently if the requirements of a circuit are re-evaluated from a physical standpoint compared with the physical properties of a transistor, new circuits can be devised that take full advantage of the transistor's capabilities. Attention is called here to the two polarities, *n-p-n* and *p-n-p*, of transistors — a condition nonexistent in tubes. Especially in power supply regulation circuits does the two-polarity property come in handy. Also audio power amplifiers sometimes profit from the unique push-pull and parallel connections made possible with a pair of transistors of opposite polarity.

2. Switch:

a. Low-level chopper (competition with electromechanical choppers). Because of the high circuit efficiency of junction transistors, they are finding application in the conversion of small d-c signals to a-c and vice versa in conjunction with d-c amplifiers.

b. Medium-level switch. (1) Multivibrator-type circuits (competition with tubes): They offer smaller size, greater reliability, and greater power supply efficiency when replacing tubes in digital and pulse type circuits.

(2) Relay (competition with electromechanical relays): As a non-regenerative switch they can often replace conventional relays where some small on voltage and off current can be tolerated.

c. High-level switch. (1) Power supply regulation (competition with magnetic amplifiers): By operating the transistor

as a series element in the a-c leg of a regulated power supply, power transistor switches, under pulse-width modulation, may serve as improved replacements for magnetic amplifiers in power supplies.

(2) Power control (competition with electromechanical controls): As the power ratings of transistors rise, they may find application as replacements for solenoid-operated electrical controls.

3. Transistor switch-saturable core circuits:

a. Communications (competition with tubes);

b. Computation (competition with tubes, relays and magnetic amplifiers);

c. Control (competition with tubes, relays and magnetic amplifiers); and

d. Power supplies (competition with tubes, magnetic amplifiers, electromechanical vibrators, rotary inverters, and dynamotors).

Semiconductor Devices

Of the many semiconductor devices, the preceding listing concerns only the junction transistor. Below is a tabulation of a number of new semiconductor devices that have been introduced, many of which are already available commercially:

1. Diodes and rectifiers
   a. point contact,
   b. junction, and
   c. "Townsend" (VR breakdown);
2. "Transistors"
   a. point contact,
   b. junction triode,
   c. junction tetrode,
   d. field effect,
   e. analog,
   f. avalanche,
   g. double-based diode,
   h. hook,
   i. Fieldistor, and
   j. intrinsic barrier;
3. Photoelectric devices
   a. point contact photo diode,
   b. junction photo diode, and
   c. junction photo transistor;
4. Infrared silicon optics;
5. Solar batteries;
6. Atomic batteries; and
7. Thermistors.

While not all of the above items are electronic, they indicate nevertheless the scope of semiconductor device activity. The transistors listed go far beyond the simple junction transistor which has dominated the discussions herein. Some of the other types such as the field effect and analog transistors have high input impedances and are much more analogous to a vacuum tube. The point contact, avalanche, and hook transistors have built-in instabilities making them especially suitable as regenerative switches and as oscillators. Junction tetrodes and intrinsic barrier transistors are designed primarily for high-frequency applications, and the double-base diode has unique properties as a switch and as a generator of special waveshapes.

Conclusion

It is evident that the junction transistor and diode are capable of a successful entrance into practically all phases of electronics. When one considers all types of semiconductor devices now known — the developments to date in saturable cores and magnetic amplifiers, the activities associated with dielectric amplifiers, and the solid state devices yet to be invented or discovered — it is apparent that the solid state electronics era is here. It is safe to assume that transistors will play a major role in this new electronics.

Discussion

Edwin W. Templin (*Westrex Corp.*): First, is there something published about the "hushed" transistor you mentioned? Second, is a special type of transistor used for best application of the "hushed" transistor circuit?

Mr. Hurley: No special transistor is required. Even quite noisy ones can be hushed. The best reference is the December 1955 and the January and February 1956 issues of *Tele-Tech*. It's a three-part article by Volkers and Peterson of Millivac.

Vaughn C. Shaner (*Eastman Kodak Co.*): In the field of motion-picture film processing, which is a chemical engineering field, we have electromechanical control devices which are subject to corrosion problems with acetic acid vapors, etc. Would you say that transistors offer better corrosion resistance in this type of application?

Mr. Hurley: In order to protect their surfaces, transistors would have to be enclosed in some kind of container with a hermetic seal. It might be all glass, as one possible answer. Normally its a metal to glass hermetic seal. As the field develops higher power ratings and lower leakage currents, transistors certainly should be applicable in film processing.

Progress With Transistors

By BURTON R. LESTER

Advances in transistor-device technology and production are hastening the introduction of this device in motion-picture and television equipment. This paper reviews the progress in device characteristics—i.e., gain, bandwidth, frequency, noise, power and life survival; the effect of tremendous increase of usage in the portable-radio, automobile-radio and computer industries on quantity production and unit price; and the net result in providing devices which meet the needs of the television and motion-picture fields.

THE ELECTRONICS INDUSTRY'S immediate and widespread acceptance of the *transistor* has been phenomenal. This device invented less than nine years ago has grown to a 50 million dollar industry in 1957. It is conservatively estimated that it will reach 250 million dollars in 1967.

Presented on May 3, 1957, at the Society's Convention at Washington, D.C., by Burton R. Lester, General Electric Co., Electronics Park, Syracuse, N.Y.
(This paper was received on May 16, 1957.)

Basically, the transistor performs the functions of an electron tube. It is not directly interchangeable nor will it entirely replace the electron tube.

The transistor is almost the opposite of the electron tube. It is a low-voltage high-current device whereas an electron tube favors high-voltage low-current operation. The low input impedance and relatively high output impedance of the transistor are the inverse of the electron tube impedances. Finally, the transistor is more nearly a current gain device as compared to a voltage gain for the tube.

The automobile radio supplied the need which speeded the development of the germanium power transistor in 1956. In use, this transistor, even though four to five times more expensive than the equivalent electron tube, replaces the tube vibrator and power supply at a cost reduction and with greater reliability. Transistorization of the signal portion of the automobile radio will occur when the transistor complement price equals the tube complement price including sockets and extra components.

The transistor is also receiving widespread acceptance in telephone and digital computer industries. The transistor is a very efficient switch. Its low saturation resistance enables it to operate at better than 95% efficiency under pulse conditions. The additional factors of small size and high reliability result in

reduced equipment size, less air-conditioning facilities, maintenance and operation costs.

Applications in Television

Television will be the next major industry to employ transistors extensively. Acceptance in broadcaster equipment will be based on different criteria from those for consumer sets. Both require technical feasibility. Initially, economics favor the broadcaster who is using portable equipment, needs less maintenance and wants reduced power requirements and the resultant reduction in plant space and air-conditioned facilities.

Studio and station equipment will undoubtedly follow the telephone and computer trends. The additional time required to prove-in prototype equipment and demonstrate reliability will lengthen the initial design and production-time cycle over that required for tube equipment. Technically, presently available transistors can meet all of the audio, switching and low-level video requirements. Intermediate-frequency and radio-frequency devices are just becoming available. High-power sweep amplifiers will be a natural outgrowth of the automobile radio power transistor work. Medium and high level video amplifiers and also radio-frequency amplifiers will require considerable development time and additional invention.

In audio preamp, signal and power amplifier applications, the transistor is equivalent to electron tube performance. Improved processing has reduced the internally generated noise which initially limited transistors in low-level application. Most production transistors have noise figures under 10 db. There are types available with less than 3 db of noise. In addition, the rugged mechanical construction of the transistor elements eliminates microphonic noise. Stable audio power gains of 45 db can be realized with transformer coupling. Resulting mismatch in low-level resistance coupled circuits introduces 6–10 db loss in power gain. Class A power outputs up to 8 w, and Class B up to 20 w are attainable. Transistors give a superior performance on low-input impedance circuits. Output impedances of power amplifiers are low enough to permit direct drive to speaker voice coils.

The small size of transistors and possible elimination of output transformers make equipment compact and extremely light. Flashlight batteries will provide hundreds of hours of operation on low-level circuits. High-power amplifiers will require storage batteries or voltage regulated power supplies. Low-voltage high-current power supplies utilizing germanium rectifiers and a power transistor voltage regulator are extremely efficient and compact.

Transistors developed for the computer industry meet most of the pulse requirements of the composite sync generator. Rise time in the order of 0.1 μsec can be obtained with these transistors. With the exception of the line drivers, or output circuits, the transistor and associated circuitry perform the function of a single electron tube triode. Two transistors would be required for each dual triode. In the case of line drivers, push-pull amplifiers will just meet the output requirements of $4\frac{1}{2}$ v across a 37.5-ohm load. Hybrid operation, with tubes used in this latter function, may be the answer until higher power, high-frequency switch transistors are available.

In a hybrid, sync generator transistors would replace 80% of the electron tubes, and power supply requirements would be reduced to one-fourth of that formerly required. A consequent weight reduction of 50% could be effected in the sync generator and its associated power supply. Most of the remaining power and weight are still required by the cabinets, vacuum tubes and associated power supply.

A completely transistorized sync generator, using only $\frac{1}{30}$ of the power required by its electron tube counterpart, would weigh $\frac{1}{5}$ to $\frac{1}{3}$ as much depending on the cabinet redesign.

The automobile radio power transistor will handle the vertical sweep amplifier assignment for image orthicons and picture tubes. The horizontal sweep amplifier is another matter. In this use, the transistor must be capable of delivering 5 to 10 amp and of withstanding fly-back peaks of 120 v. The peak inverse voltage requirement is the exacting one. Present power transistors withstand peaks of 50 v and would require a threefold improvement. This transistor is also the one missing item for the battery-operated portable TV set. Pressure from set manufacturers could speed the development of this transistor and make it available within the next two years.

With the exception of noise level, transistors outperform tubes in 5- to 8-mc wide-band video amplifier circuits. The inherent low microphonic noise in these devices removes the necessity of high peaking and simplifies circuitry. The noise level is higher than present electron-tube circuits but more than adequate for image-orthicon use. Specially selected low-noise transistors will meet the requirements of the vidicon camera tube. As in the case of the line driver, present transistors are not capable of providing sufficient drive for picture tube operation. Here again pressure from the portable TV set manufacturer could bring about the high G_m picture tube as the answer. Vidicon cameras can be completely transistorized; and with the exception of the horizontal sweep amplifier, present image-orthicon cameras could be completely transistorized at considerable power and reliability savings. This should be of considerable interest in portable and color camera chains. In the picture monitor, again the video output drive and horizontal sweep amplifier are the only circuits not capable of immediate transistorization.

While size, weight and power requirements provide impetus to transistorization of TV equipment, reliability will be the major factor. By the end of this year, well over a million and a half transistor portable radios will have been produced. In most of these sets the transistors are soldered directly into printed circuit boards. General Electric has had a one-year warranty on our transistors for the past two years. Returns during this period have been less than 1%. Quality control life tests on shipped transistors indicate less than 5% failure at 1000 hr. These tests are run at maximum ratings and cycled on and off every hour and are far more severe than normal customer usage. One quality control lot started in test May 24, 1954. Of the original lot of 43 units, four failed during the first 24 hours. Since then, there have been no failures or noticeable change in average characteristics. These units with over 24,000 hours of life are still on test. Incidentally, we now age all of our transistors for 24 hours to eliminate early failures.

Cost Developments

The final factor governing transistorization of television is the price of the transistor compared to the electron tube. In 1955, transistors for portable radios were priced at five to six times the equivalent electron tube cost. By 1956, the price ratio had dropped to three to four times the cost and by the end of 1957, transistors will be selling at a little more than twice the cost of tubes. A similar price pattern will hold in television. Addition of new types has raised the initial average price ratio of all types again to the order of seven to one. This ratio will drop as the industry builds up and increases production of these new types.

In summary, more than 80% of the circuits contained in TV equipment can now be transistorized with a marked increase in reliability and consequent cost reduction in maintenance.

The reduction in size, weight and power requirements while of greatest interest in portable equipment also simplifies studio requirements and operation costs. These factors offset the initial high cost which will actually drop in a pattern similar to radio transistors over the past three years.

A Transistorized Seven-Position Portable Mixer

By KURT SINGER

A seven-position portable mixer has been transistorized throughout. Its electrical facilities and mechanical construction are described fully, including a detailed circuit description of the individual transistorized amplifiers and explanation of constructional features. Excellent stability, low distortion and a very good signal-to-noise ratio have been obtained with this equipment.

In the fall of 1955 we were given the task of providing a 7-channel portable recording unit. Since it was intended to use the equipment anywhere in the world, portability and operating convenience, together with studio-type quality, were the requirements. After weighing the pros and cons of several alternatives, we decided on the use of vacuum-tube operated microphone amplifiers located directly at the microphone boom, together with a completely transistorized 7-channel portable mixer.

This portable mixer was to house all necessary equipment required to amplify and control the output from the microphone amplifiers (approximately zero dbm) to a level sufficient to excite the magnetic recording heads. All amplifiers used in this assembly are identical and are completely transistorized. Three amplifiers are used per channel, namely: one booster amplifier, one recording amplifier and one monitor amplifier. In addition, a talk-back microphone booster amplifier, a spare amplifier to be used in emergencies and a 400-c oscillator for set-up purposes are provided in the mixer case. A total of 23 amplifiers and one oscillator are assembled in a common enclosure.

Before proceeding with the description of this mixer, let us elaborate on this transistorized universal amplifier known as the MI-10170 or the MI-10170A. This amplifier has been constructed as a plug-in unit, which is shown in Fig. 1. All components, as well as transistors, are fully enclosed so as to be shielded electrically and protected mechanically. Upon removal of the cover, all components and transistors become accessible (Fig. 2). The circuitry of this amplifier is represented in Fig. 3. Four transistors are used in a circuit containing a voltage stage, a driver stage and a push-pull output stage arranged in Class B complementary symmetry. Negative feedback from output to voltage stage collector stabilizes the gain, reduces distortion and also furnishes low-frequency recording tipup when the amplifier is used to drive the recording head.

The complementary symmetry configuration was used for the output stage for the following reasons:

(1) Complementary symmetry eliminates the output transformer and phase inverter generally needed in conventional circuits.

(2) Achieving stable inverse feedback in traditional transistor push-pull amplifiers might require troublesome balanced driver stages with an increase in the total number of transistors used.

(3) Good *n-p-n* transistors are commercially available.

The complementary symmetry output stage was connected common collector because this arrangement is generally more linear and d-c stable than the common emitter connection for this particular amplifier. The 100% voltage feedback between the base and emitter in the common collector connection minimizes distortion caused by unlike alpha, input nonlinearity, alpha falloff and load variations, compared to the common emitter circuit. In addition, changes in collector current due to temperature rise are reduced by the d-c feedback in the base-emitter circuit of each output transistor. The variation in collector current is reduced further by the addition of the resistor R15 and R16 in each emitter lead.

This stabilization operates as follows: When the collector current is changing due to temperature, a voltage developed across the resistor in the emitter lead causes a current to flow in the base circuit of the transistor in a direction to reestablish the desired operating point. Five per cent of the available output power is dissipated in these stabilizing resistors, but the reduced efficiency is easily worth the stabilization achieved. A forward, base bias, voltage sufficient to cause approximately 0.3-ma collector current to flow is applied to the output transistors to remove the last vestige of crossover distortion that remains.

The base-bias network serves another function in permitting a single-polarity power source to be used instead of separate positive and negative supplies generally employed with complementary symmetry circuits. This network establishes a half-supply voltage point at the junction of R12 and R13. The d-c voltage at the junction of R15 and R16 is approximately that at the junction of R12 and R13 due to the emitter follower action of the output stage. By making the collector-to-emitter voltage of each output transistor equal, a single-polarity voltage supply serves to establish the proper collector emitter bias for the *p-n-p* and *n-p-n* transistor. The output stage will accept transistors with betas of 20 to 100 and a beta unbalance between *p-n-p* and *n-p-n* units of 5 to 1 with essentially no deterioration in output signal or stability.

Although the above described output stage is quite linear and d-c stable, it suffers a serious defect in having a low power gain of only 15 db. This low power gain and particularly the high input signal voltage (8-v rms), needed for full power, impose a stringent requirement on the driver stage. In fact, the driver is probably the most critical stage in the circuit from distortion and dissipation considerations. In order to achieve the high-voltage, driver signal with dis-

Presented on October 12, 1956, at the Society's Convention in Los Angeles by Kurt Singer, Commercial Electronic Products, Radio Corp. of America, 1560 N. Vine St., Hollywood 28.
(This paper was received on January 7, 1957.)

Fig. 1. Transistorized universal amplifier, M1-10170A.

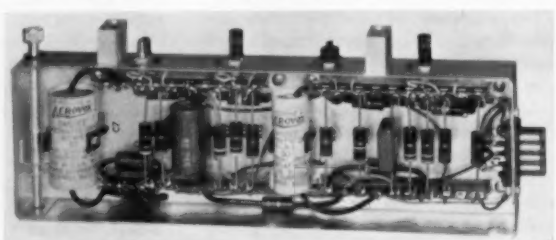


Fig. 2. Uncovered amplifier, M1-10170A.

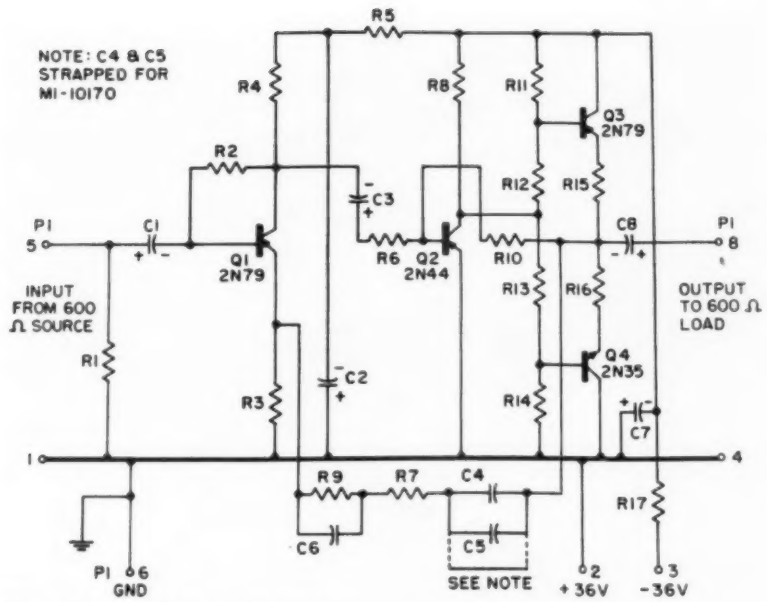


Fig. 3. Circuitry of M1-10170A amplifier.

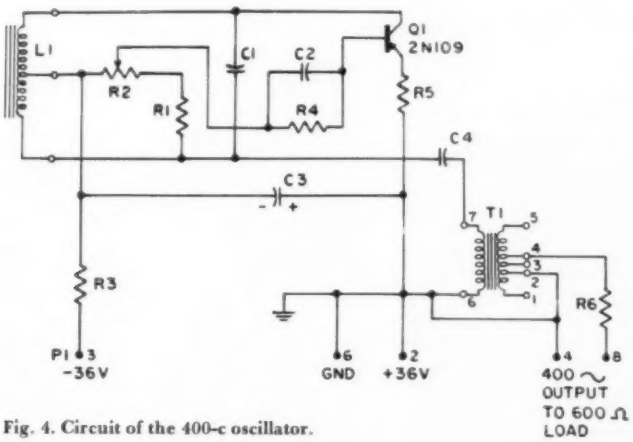


Fig. 4. Circuit of the 400-c oscillator.

tortion as low as the output stage (approximately 2.5% without feedback), a 50-mw collector-dissipation operating point was required for the driver. A transistor with a collector dissipation rating of 150 mw is used here for reliability. With the driver collector voltage about equal to that at the junction of the input resistors R12 and R13, direct coupling is possible between driver and output stage. In addition, by returning the base bias resistor R10 to the junction of the series emitter stabilizing resistors R15 and R16, d-c feedback is accomplished over the output stage to further stabilize the operating point of the driver-output stage circuit.

The voltage stage is conventional and capacity-coupled to the driver. Negative feedback from the output, that is, the junction of R15 and R16 to the emitter of the input stage, accomplishes gain stabilization, flattening of frequency response and also low-frequency recording tipup when required. When this amplifier is used as booster or monitor amplifier, capacitors C4 and C5 are strapped so as to provide flat frequency response. When operating as magnetic recording amplifier, then the conventional low-frequency tipup of 6 db at 60 c is required. In order to accomplish this, the strap across C4 and C5 is simply removed. The input impedance of this amplifier is approximately 600 ohms. The amplifier was designed to work into a load impedance of 600 ohms, although its actual output impedance is in the order of 50 ohms or less due to liberal use of negative feedback. The power output capabilities are +18 dbm at 0.5% distortion or less. The frequency characteristic is flat from 20 to 20,000 c when used as booster or monitor amplifier. The gain of the amplifier when working between impedances of 600 ohms is 40 db; the noise level at its output is less than 0.5 mv. The power requirements are 36 v at a current from 8 to 14 ma, depending upon output level.

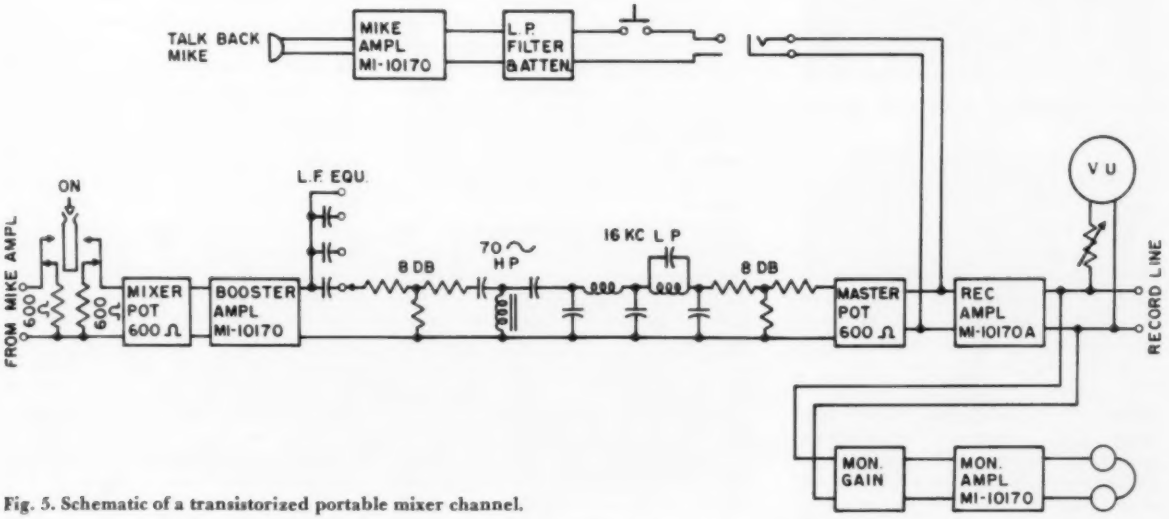


Fig. 5. Schematic of a transistorized portable mixer channel.

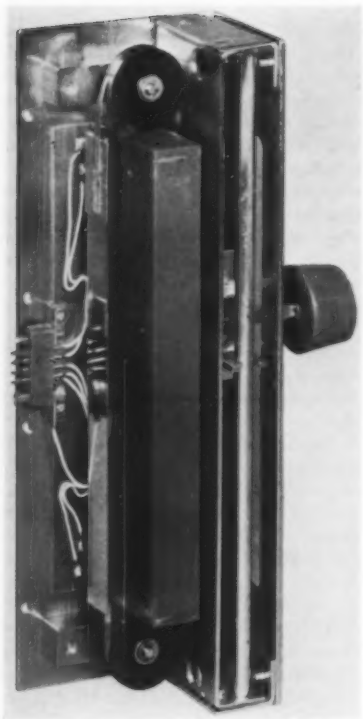


Fig. 6. Linear construction of new ladder-type attenuator.

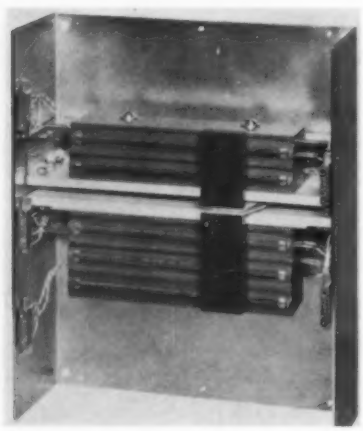


Fig. 7. Five linear mixer pots ganged together.

The 400-c oscillator, the circuit of which is shown in Fig. 4, uses a single 2N109 transistor in a more or less conventional circuit. An adjustable feedback control is incorporated to permit operation with just enough feedback so as to satisfy the requirements of stable operation and minimum distortion, which is on the order of 0.5% or less.

Proceeding now with the description of the portable mixer, each channel contains three transistorized amplifiers, namely one booster, one recording and one monitor amplifier. In addition, there is provided variable dialogue equalization consisting of three steps of 5 db at 100 c for each channel. A 70-c high-pass filter and a 16,000-c low-pass filter have also been included. An overall simplified circuit-schematic of the mixer is shown in Fig. 5. The output from each microphone amplifier goes to its own cutoff key and variable, ladder-attenuator, mixer pot. The output of each mixer pot is fed to the booster amplifier, from there to the dialogue equalizer 70-c high-pass filter, 16-kc low-pass filter, and finally to an overall master. The overall masters of channels 1 to 5 are ganged together so that they can be operated simultaneously from a single control knob. Channels 6 and 7 have separate overall masters. The output of the overall master pots is fed to the recording amplifiers and from there by means of two special cables to the 7-channel recorder. The output lines are bridged by VU-meters, each with its own VU-range attenuator. Seven monitor amplifiers are also bridged across the recording lines, which permit headset monitoring of each individual channel or of the combined outputs of all 7 channels.

Fig. 8. Model of the 7-position portable mixer.

A talk-back microphone with its own microphone amplifier and an intercom system which permits communication between the mixer, the microphone boom man and the recordist have also been incorporated. The ladder-type attenuators are of a new and improved linear construction. A single attenuator is shown in Fig. 6. The resistance unit is encapsulated in epoxy resin and only the area in contact with the wiper arm is exposed. Figure 7 shows 5 linear mixer pots ganged together. This unit is used as the overall master for channels 1 to 5 and has been developed specifically for this 7-channel mixer.

The external appearance of this unit is shown in Fig. 8. On the control panel are the 7 individual mixer pots with the cutoff keys directly above and the dialogue equalizer knobs directly above them. On the righthand side are the three overall master knobs, the first one controlling overall masters for channels 1 to 5 and the others, channels 6 and 7, respectively. Directly above the overall masters are 7 individual monitor amplifier gain controls. The top knob on the farthest right controls selection of monitor amplifier outputs for headset monitoring. The retractable turret at the back of the control panel contains 7 VU-meters and their individual VU-range attenuators. The internal construction of the mixer is shown in Fig. 9. Underneath the control panel are the 7 individual mixer pots to the left, the talk-back microphone in the center and the overall master pots to the right. The back side of the VU-meters and VU-range attenuators can be seen directly below.

The bottom of the mixer case is filled with 24 transistorized amplifiers which have been described before. Each channel is constructed as an individual unit which contains the 3 plug-in amplifiers, high-pass and low-pass filters, isolation pads, power-on and -off switches and high-pass filter in- and out-switch. By means of single-circuit jacks contained in each channel it is possible to transfer the output from the talk-back amplifiers to any of the 7 recording channels. This facility assures that the recordist can get

Fig. 9. Internal construction of the 7-position portable mixer.

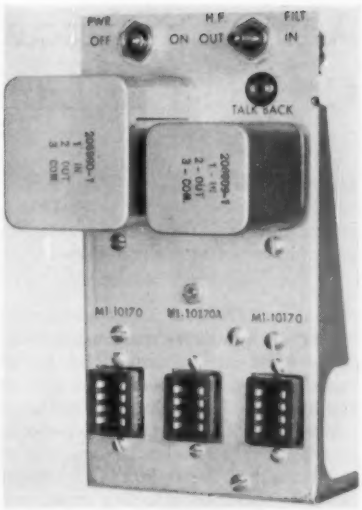


Fig. 10. Mounting bracket for amplifiers and channels.

the talk-back microphone signal on any of the recording amplifiers in use. Figure 10 shows the bracket on which all the components and amplifiers for each individual channel are mounted.

The power requirements for the mixer are 36 v at 0.35 amp, which constitutes the input power for all transistorized amplifiers; 18-v d-c is also supplied, which is used to energize 7 relays connecting the 400-c oscillator output to the recording channels and to illuminate the VU-meter lights. The back view of the mixer (Fig. 11) shows the external connections. The 3 female plugs supply 3 microphone amplifier cabinets, which contain a total of 7 microphone amplifiers. The 2 male plugs contain the 7 recording lines, power and signaling circuits. The 18-v circuit is also used to furnish heater voltage to the microphone amplifiers. A separate 250-v line is brought in for B supply of the microphone amplifiers. The mixer with its cover, ready for transportation, is shown in Fig. 12. It can be removed quite conveniently from the stand to facilitate storing and/or transporting. The weight of the mixer complete with all amplifiers is 70 lb; its length, 34 in.; width, 17 in.; height, $10\frac{1}{4}$ in.

It may be of interest to summarize the performance of the overall recording channel in which this transistorized mixer is used. The microphone amplifiers have a gain of 72 db, whereas the maximum gain of the mixer is 52 db. The two amplifiers in the mixer, namely booster and recording amplifiers, have a total gain of 80 db; however, we must deduct the insertion losses of the mixer pot and the overall master, which total 12 db. There are also two 8-db pads incorporated for isolation purposes. Consequently, the total channel gain is 124 db, which is more than adequate to cover any situation that might arise. With average dialogue recording levels, a signal-to-noise ratio from 55 to 60 db is easily obtained for the electrical channel. The overall signal-to-noise ratio, including the magnetic recorder, referred to a 1% distortion criterion, is on the order of 55 db.

In order to assure a minimum of difficulty in the field when replacing transistors, matched sets are supplied for each amplifier. The transistors are selected for low noise for the first amplifier stage and for minimum distortion at maximum output and also at a level 20 db below maximum. No replacements of transistors have yet been found necessary, and no change of characteristics or signal-to-noise ratio has occurred during the many months' service the equipment has provided to date. This speaks well for the stability of the transistorized amplifiers and it is our intention to extend transistor operation also to microphone and magnetic playback amplifiers in the near future.

In conclusion, I should like to thank A. I. Aronson of the Camden Advanced Development Group for the development of the basic circuit of the MI-10170 amplifier and to mention that its circuit explanation was his contribution.

Fig. 11. External connections, back view of mixer.

Fig. 12. Mixer, prepared for travel.

Automatic Recarboning of Carbon-Arc Lamps

By J. P. LATIL

This paper describes some of the methods used to operate high-intensity carbon-arc lamps continuously for several hours. The cost of special carbons and other factors limit their use. The development of less expensive methods would be a great improvement of the carbon-arc lamp.

The high-intensity carbon-arc lamp is the brightest source of light. But it cannot give many hours of continuous operation like incandescent or discharge lamps, unless it is equipped with a special recarboning mechanism. When one of the two carbon electrodes of a carbon-arc lamp in operation is nearly consumed, an operator must turn off the current, remove one or both stubs and place new carbons in the mechanism of the lamp. For some applications of the lamp, this interruption is not acceptable; the lamp should operate continuously for long periods of time. For other applications, short interruptions every hour or two are acceptable, but the recarboning should be fast and entirely automatic. We are going to describe some of the devices which are used to obtain long periods of operation by automatic recarboning.

Joining the Positive Carbons

In high-brightness d-c carbon arcs the consumption of the positive carbon is high. For instance, in a 200-amp arc lamp, which has a brightness of 1600 candles/sq mm, the 11mm water-cooled positive is consumed at a rate of 40 in./hr. A 22-in. long carbon must be replaced every 30 min. If more than a half-hour of continuous operation is required, "joined" positive carbons must be used.

The joined carbons cannot be allowed to slip in relation to each other while they rotate and while they move longitudinally. Several methods of joining positive carbons have been devised. Droll,* for instance, and McCarty† have patented metal sleeves which hold the consecutive carbons together and assure a "continuous" supply of positive carbons. But the introduction of a metal sleeve in the arc may create a disturbance of the arc.

In the Super Ventarc Lamp,[1] the positive carbons are nonrotating, which makes the joining problem easier. The positive carbons are designed as shown in Fig. 1, so that the core of the carbon protrudes at one end with a complementary hole formed at the other end. A magazine holding positive carbons is provided in the lamphouse.

As soon as the length of the burning carbon reaches a certain value, a contact is automatically made which causes a new carbon to leave the magazine and be joined to the burning carbon, the hollow end of the new carbon sliding over the protruding core on the cold end of the burning one. The parts to be joined are impregnated by the manufacturer with a special cement. As the joint moves toward the positve head, it is heated by a simple electrical oven which hardens the cement. The magazine can be designed to take any quantity of positive carbons and it can be refilled while the arc is burning.

In the Genarco method,[2] the carbons are joined without cement. Both ends of each carbon are machined (Fig. 2). The female tapered end of the new carbon is driven by a spring laden piston toward the male tapered end of the consumed carbon and secured solidly. When being fed into the arc, the joints cause so little disturbance that in many cases the passage is not even noticed by an untrained observer. This method of joining the carbons has the advantage of not introducing in the arc any foreign matter such as glue or metallic sleeve; but the machining of the tapered ends of the carbons is expensive.

The carbons are not placed one by one in the magazine, but they are placed by the manufacturer in light-metal cases or "clips" which contain several machined carbons. The operator places a clip in the magazine before operating the lamp and he does not have to manipulate or even touch the carbons.

In the Navy Aircraft Searchlight Model AN/AVQ-3, manufactured by the Bosch Arma Corp., and used for antisubmarine warfare, space for the positive carbon is very limited. A magazine (Figure 3), made by Genarco Inc., contains one 8-in. long, 11mm diameter cored positive carbon and four 4-in. long additional carbons. The total usable length of these carbons is 21 in., which is enough for 50 min of operation. The magazine mechanism must operate in every possible position without being affected by gravity. It operates only for a few seconds for each joining and the power required is only 2 w. This small power is supplied momentarily by the positive carbon feeding mechanism.

In the Army General Purpose Searchlight, the Genarco Arc Lamp Model P.1 contains a clip with 10 carbons 10 in. long. The clip can be removed while the lamp is in operation and replaced by a full clip. In the Genarco Arc Lamp Model P.3, the clip contains 15 carbons and is inserted in a slot located near the top of the searchlight. When all or most of the carbons are consumed, every $3\frac{1}{2}$ hr, the operator pulls out the clip and removes it, either empty or with some unconsumed carbons. He replaces this clip with a new clip containing 15 carbons. This operation does not require the opening of the searchlight or the interruption of the searchlight operation.

The Negative Carbon

As the consumption of the negative carbon is much lower than that of the positive, it is often possible to use one long negative rod while several rods of joined positives are being consumed.

If the length of the negative carbon is not sufficient, a negative graphite disk (Fig. 4) or ring can be used. It rotates slowly around its center and the negative foot-point maintains a definite location with reference to the positive carbon. The use of negative disks is not a recent

A contribution submitted on April 29, 1957, by J. P. Latil, Genarco, Inc., 97–04 Sutphin Blvd., Jamaica 35, N.Y.

* U. S. Pat. No. 2,120,243.

† U. S. Pat. No. 2,657,326.

Fig. 1. Super Ventarc Positive Carbon. This positive carbon is designed so that the core of the carbon protrudes at one end with the complementary hole at the other end.

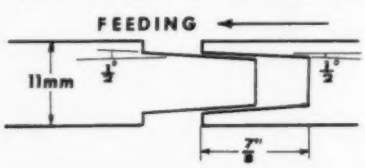


Fig. 2. Section of two Genarco machined carbons ready to be joined.

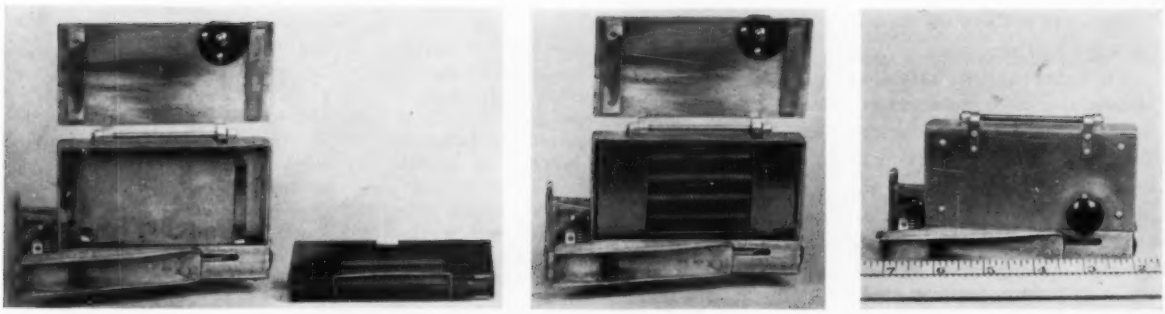


Fig. 3. Genarco Positive Carbons Magazine for Bosch ARMA-Navy AN/AVQ3 Anti-Submarine Searchlight. Left: The magazine is shown opened and empty. On the right is a metal "clip" with four 4-in. long machined carbons. Center: The clip has been inserted in the magazine. The serviceman will now pull out the retaining wire which releases the carbons from the clip. Right: The door of the magazine has been closed.

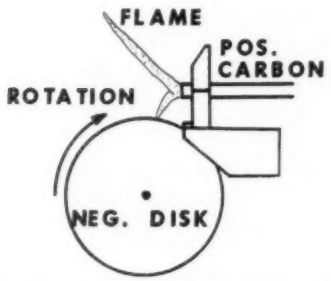


Fig. 4. Arc between a negative graphite disk and a positive cored carbon.

development. During World War II, several German- and British-made lamps used this type of electrode.[3]

While the disk rotates slowly, its center moves toward the positive carbon to maintain a constant gap or a constant current, depending on the type of lamp. The same disk can be used continuously for 10 hr or even 20 hr, depending on its diameter and the lamp characteristics.

Long Periods of Operation With Short Outage for Recarboning

Several mechanisms have been devised in which the lamp is turned off automatically when the positive carbon is nearly consumed. The stub is promptly ejected and replaced by a new carbon; the arc is struck automatically. The outage lasts 10 to 30 sec, depending on the mechanism. This method has several good features:

(a) The mechanism is faster than an operator (and in military operation not subject to emotion);

(b) The mechanism operates in a situation where the operator has no access to the lamp (military searchlight attached to the turret of an Army tank);

(c) Standard carbons can be used, which are neither as expensive nor as fragile as the special carbons described heretofore.

The method has an obvious disadvantage: for a few seconds during the recarboning, no light is available. This may not be a drawback, however, when the arc lamp is used for the production of high temperature, in an industrial process in which a short outage every hour or two is not detrimental to the process.

In the British Army Lamp Searchlight H.C.D. 90 CM, Mark III, the negative carbon is a long rod suitable for 5 hr of operation. The positive carbons are placed in a vertical magazine which operates by gravity. When a positive carbon is nearly consumed, a new carbon pushes the stub, ejects it and replaces it in the arc. The outage is a few seconds.

In the Genarco Searchlight AC.1 Model T.3 for M-48 Army Tank,[4] the arc lamp operates on 400-cycle current. The two carbons are identical and operate for 2 hr without recarboning. Ten minutes before the two original carbons are consumed, a red pilot-light lights up on a panel board. The searchlight operator has an option to press a recarboning button. If he presses it, the lamp turns itself off, the two carbon stubs are removed and replaced with two new carbons in the lamp, and the arc is struck. The whole operation takes less than 30 sec. If the operator does not use his option, the recarboning takes place automatically at the end of 2 hr of operation. Therefore, without attendance and with the magazines and the lamp fully loaded with five trims of carbons, the arc lamp operates for 10 hr, with 30 sec interruption every 2 hr.

Construction of an Arc Lamp Operating for Several Hours

The methods which have been described to recarbon an arc lamp automatically do not solve another problem which faces the designer of the lamp. Most lamps that have been designed to operate for $\frac{1}{2}$ hr or 1 hr without interruption, cannot operate for several hours without being turned off for cooling and maintenance, especially very-high-brightness and high-consumption lamps.

Troubles which do not appear when a lamp can cool off after a short period of operation may occur after several hours of continuous operation without cooling-off periods. Ashes, carbon particles or oxides may be deposited at several points such as the reflector, auxiliary mirrors, positive contacts or electric probes. They reduce the efficiency of the lamp or prevent its proper operation. The temperature of certain parts may get higher than is permissible and they may expand more than an acceptable length. Lubrication of working parts may become insufficient and metallic parts may oxidize.

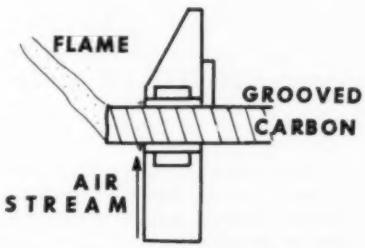


Fig. 5. Grooved positive carbon. The grooves machined on the surface of the positive carbon push the ashes or other particles, that condense between the very cold contacts, into an airstream where they disintegrate. Thus, the contacts are maintained constantly clean.

The lamp designer has to provide a more efficient cooling of all parts which may overheat. The combined use of air and water as a coolant is often required. Condensation of ashes or oxides on the cooled parts must be prevented. This can be done, for example, by using strong curtains of air or by propelling or attracting the particles with electrically charged shields.

After several hours of operation, particles have a tendency to condense between the strongly water-cooled positive contacts of very-high-brightness lamps. A simple method of cleaning the positive contacts continuously, in the P.1 Genarco Arc Lamp, uses grooves, machined on the surface of the positive carbons. These grooves, operating as an Archimedean screw, push the deposits, which may accumulate after several hours, out of the contacts (Fig. 5). An airstream removes

them as soon as they come out of the contacts and dissipates them.

The unburned particles which may be deposited on the reflector can be burned by air jets or sucked out of the lamphouse by a powerful blower. In many electrical components, silver will often give more reliable contacts than copper. A greater use of refractory material and high temperature-resisting metals (monel, tungsten, titanium) than are used in ordinary lamps is also necessary.

Conclusion

We have described several devices which are in actual use to operate carbon-arc lamps continuously and automatically. Chiefly because of the high cost of the special carbons and the magazine mechanisms, their application remains limited. Arc-lamp engineers, by using their imagination, could find new solutions. If an inexpensive and reliable method of operating arc lamps for a great number of hours continuously were devised, a decisive step would be made in the art of high-brightness lighting.

References

1. Edgar Gretener, "An improved carbon-arc light source for three-dimensional and wide-screen projection," *Jour. SMPTE, 61:* 516–524, Oct. 1953.
2. W. Finkelnburg and J. P. Latil, "A fully automatic continually operating very high intensity carbon arc lamp," *J. Opt. Soc. Am., 44:* 1–5, Jan. 1954.
3. *Symposium on Searchlights,* Illuminating Engineering Society, 32 Victoria St., London, 1948, p. 38.
4. J. P. Latil, "A new searchlight carbon arc lamp," *Illum. Eng., L:* 378–380, Aug. 1955.

Some Comments on Procedures Used to Compare Theater Screens

By YORICK G. HURD

Ways of comparing the reflecting and light-distribution properties of several theater-screen surfaces are described. Comments are made on instruments (integrating spheres, goniophotometers, spectrophotometers and brightness meters) used in comparing screen surfaces. Lenticular-screen design and "gain" formulas are presented with examples of their use in estimating a screen's performance. Data on white, "silver" or aluminum, beaded, pearl and lenticular screens are included.

Anyone interested in presenting the best quality picture possible to a theater audience will probably want to compare the various lenses, arc lamps, projectors and screens that are available. The performance of a lens can be compared with the help of measurements of transmission, resolution (side and center), flare, field uniformity, etc. The number of lumens from an arc lamp, the steadiness of the film in a gate, and the film temperature can be measured and compared. There are qualities in a screen that can be measured and compared also. Undoubtedly, some of the measurements are more important to a good picture than others, but all measurements should be considered in choosing the best lens, arc lamp, projector or screen. This paper will consider the procedures used to compare reflection properties of screen surfaces.

Any screen receiving light from a projector reflects, transmits, or absorbs various portions of the light.[1] Most of the reflected light should be directed toward the audience in a theater and not be used to illuminate walls, ceilings and stage, where it is wasted and does not contribute to a good picture. Especially in the case of large theater screens, it is desirable to increase picture brightness by reflecting the largest possible portion of the incident light toward the audience.[2] Even in theaters where adequate brightness can be obtained, a better reflecting screen means cost reduction from savings in arc current and carbon consumption.[3]

The most important physical characteristics of a screen, other physical characteristics being equal or satisfactory, are its light-reflecting efficiency and its ability to distribute projected light to the theater audience.

Apparatus Used for Screen Comparison

Beginning in 1930 and continuing to the present time, the Research and Development Division laboratories of the Twentieth Century-Fox Film Corporation have compared samples of both domestic and foreign screens, both visually and by measurement with instruments. For these purposes, it was necessary to devise and modify certain types of instruments and testing apparatus. A description of these may be helpful in understanding the data to follow.

One instrument particularly useful in

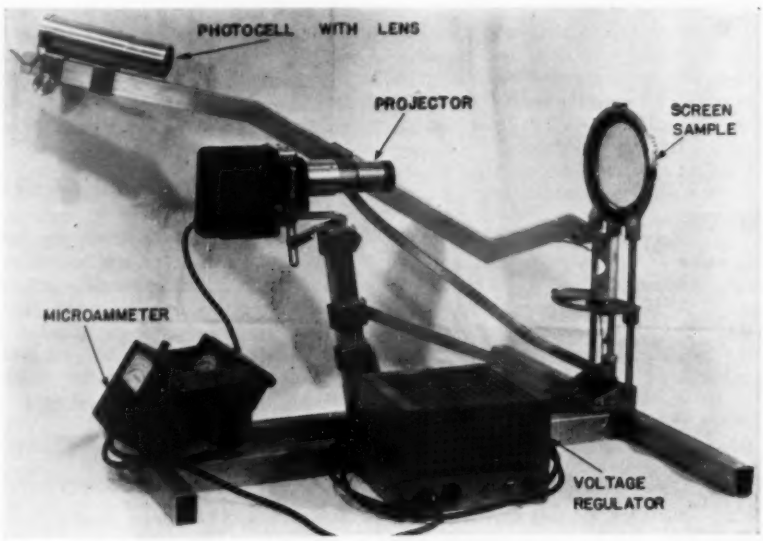


Fig. 1. Goniophotometer.

Presented on May 2, 1957, at the Society's Convention at Washington, D.C., by Yorick G. Hurd, Twentieth Century-Fox Film Corp., 444 W. 56 St., New York 19.
(This paper was received on April 3, 1957.)

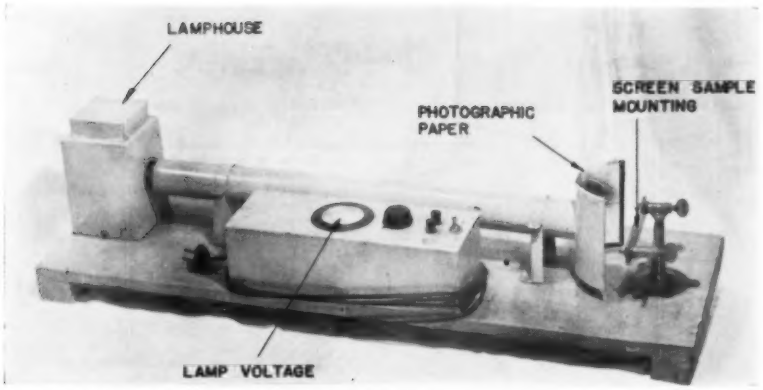


Fig. 2. Photographic goniophotometer.

determining the relative screen brightness at various angles is the goniophotometer (Fig. 1). This particular model was designed and constructed in our laboratory, but similar equipment has been described elsewhere. This type of screen-measuring equipment was used in connection with other development projects which resulted in an earlier paper presented to this Society.[4]

The goniophotometer in Fig. 1 was designed to permit the light source to be raised or lowered to simulate any theater projection angle. Also, the photocell was arranged so that it could be moved in any horizontal plane to receive illumination simulating any location in the seating area of the theater. The photocell current may then be read on a microammeter. Microammeter readings from screen samples were then compared with readings from a standard white screen of 84% total reflection, relative to magnesium carbonate. Magnesium carbonate block (which is accepted as a standard of diffuse white) and most "matte" white screens give nearly equal brightness, regardless of angle of view, whereas screens with some specularity in their surfaces and beaded screens are brighter than white screens at some angles, but dimmer at other angles.

A second form of goniophotometer, which yields qualitative information regarding the light-distribution pattern from a screen sample, is the photographic goniophotometer (Fig. 2). A piece of photographic paper or film inserted in the cylindrical holder receives light from a screen sample which is illuminated normally by a lamp at the end of a collimating tube. You will note the necessity of punching a hole in the center of the paper to permit the light to reach the screen sample. Coordinates drawn on a transparent shield inserted in front of the photographic paper can be used to check the extent and location of the light reflected from the screen sample. Typical distribution patterns are shown in Fig. 3. Those whose problem it is to design or evaluate screen surfaces will find this apparatus particularly convenient.

Another instrument useful to anyone interested in comparing the relative efficiency of screens is the integrating sphere arranged to measure reflection (Fig. 4). The screen sample, illuminated by collimated light, reflects light to every

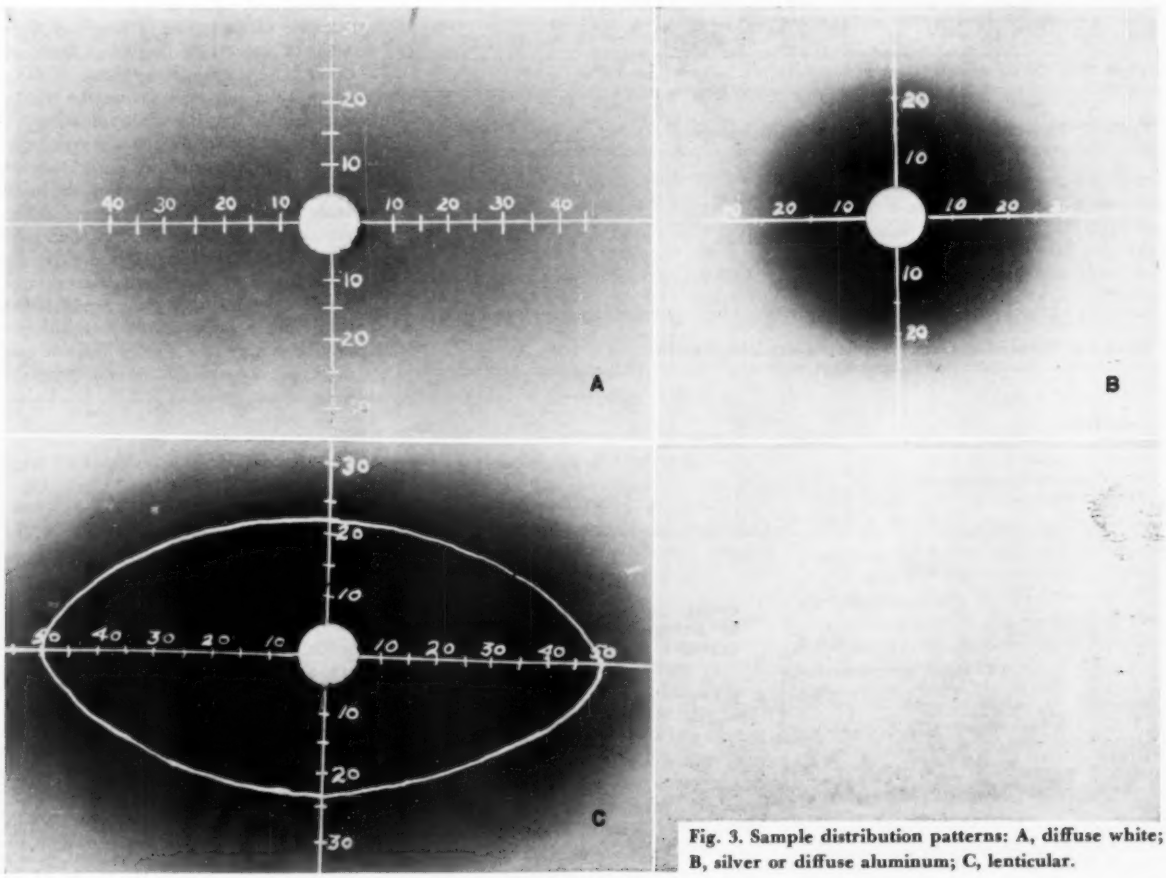
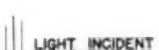


Fig. 3. Sample distribution patterns: A, diffuse white; B, silver or diffuse aluminum; C, lenticular.



known that a perfectly diffusing surface reflects light in all directions with uni-

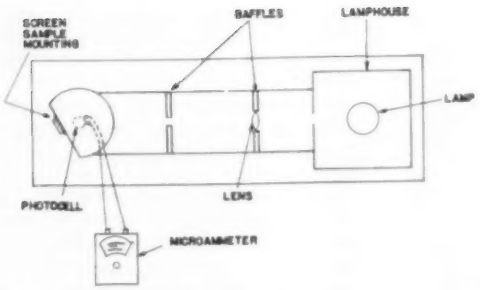


Fig. 4. Integrating sphere.

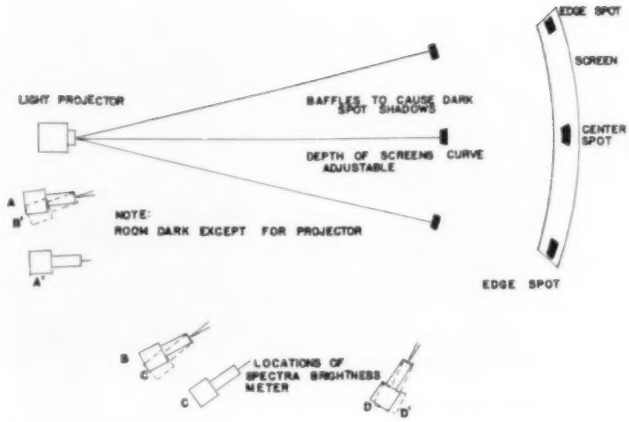


Fig. 5. Diagram of apparatus setup for measuring washout.

part of the sphere. The inner surface of the integrating sphere, which is coated with a diffuse white substance, re-reflects the light in all directions, so that the photocell receives an average of the total light reflected from the screen sample. With the integrating sphere, the higher the reading for any given type of screen, the greater the screen brightness, other parameters being equal.

Brightness meters, such as the Luckiesh Taylor, the Macbeth Illuminometer, the Spectra, or any other brightness meter which accepts a small, solid angle, can be used to measure the brightness of a screen directly.

Consideration of the uniformity of light distribution in a theater dictates the advisability of curving the screen, because of fall-off in arc-light distribution and the changes in the angle of incident light from the projector across a flat screen. Whenever a screen is deeply curved, light from one portion of the screen is re-reflected to other parts of the screen, causing reduction in picture contrast, or "washout," as this has sometimes been termed. Using a Spectra Brightness Meter (Fig. 5), a setup was made to compare the amount of "washout," or stray light from one part of a screen to another, when a screen is curved.

Subjective methods of screen comparison have also been employed at our laboratory. These comprised examination of screens installed successively in one theater, so that they could be viewed under nearly identical conditions of illumination and other ambient conditions. Unless precautions are taken, this method has certain possible shortcomings because of variation of angle of view, angle of projection, dark adaptation, and other purely subjective factors. Some of these faults may be overcome by making a composite screen and illuminating it to theater scale from a single projector. Thus, the projection distance is a constant and the screen samples are in the same plane. It is important here to keep the samples in the same plane, because if they are in different planes the specular screens will appear brighter or dimmer at some angles than they would if they were in the same plane. Evaluation of any screen surface should include both objective measurements and subjective judgments.

Table I. Theoretical Gain for Circular Distribution.

Θ Angles	10	20	30	40	50	60	70
Gain	33.4	8.6	4.0	2.4	1.7	1.3	1.1

Table II. Theoretical Gain for Elliptical Distribution.

β ↓ / α → Angles	10	20	30	40	50	60
10	33.4	16.9	11.6	8.9	7.45	6.6
20	16.9	8.6	5.9	4.6	3.8	3.4
30	11.6	5.9	4.0	3.1	2.6	2.3
40	8.9	4.6	3.1	2.4	2.0	1.8

Table III. Theoretical Gain for Rectangular Distribution.

β ↓ / α → Angles	10	20	30	40	50	60
10	26.0	13.2	9.0	6.6	5.9	5.2
20	13.2	6.7	4.6	3.6	3.0	2.6
30	9.0	4.6	3.1	2.5	2.0	1.8
40	6.5	3.6	2.5	1.9	1.6	—

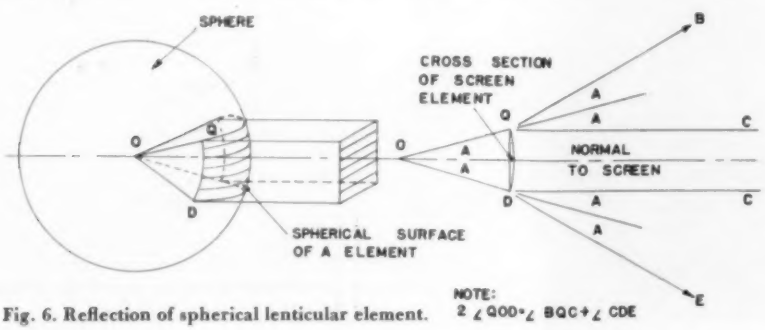


Fig. 6. Reflection of spherical lenticular element.

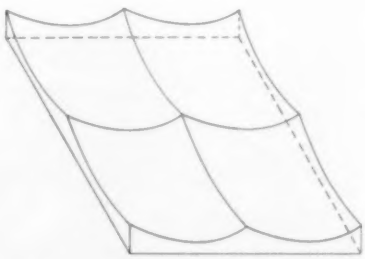


Fig. 7. Enlargement of lenticular-screen elements. When the reflecting surfaces of these elements are portions of a sphere the reflection pattern is rectangular; however, the surface could be curved to give elliptical or other forms of light distribution.

Still another equation can be used for

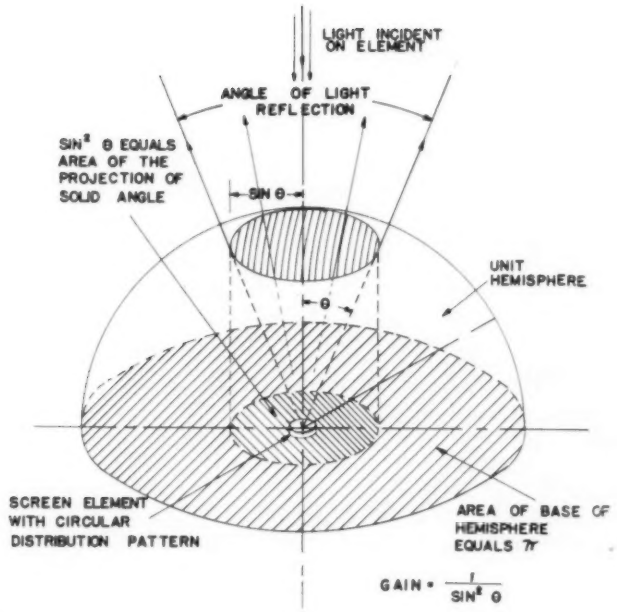

LIGHT INCIDENT ON ELEMENT
ANGLE OF LIGHT REFLECTION
SIN² θ EQUALS AREA OF THE PROJECTION OF SOLID ANGLE
SIN θ
θ
UNIT HEMISPHERE
SCREEN ELEMENT WITH CIRCULAR DISTRIBUTION PATTERN
AREA OF BASE OF HEMISPHERE EQUALS π
GAIN = 1/SIN² θ

Fig. 8. Unit sphere example.

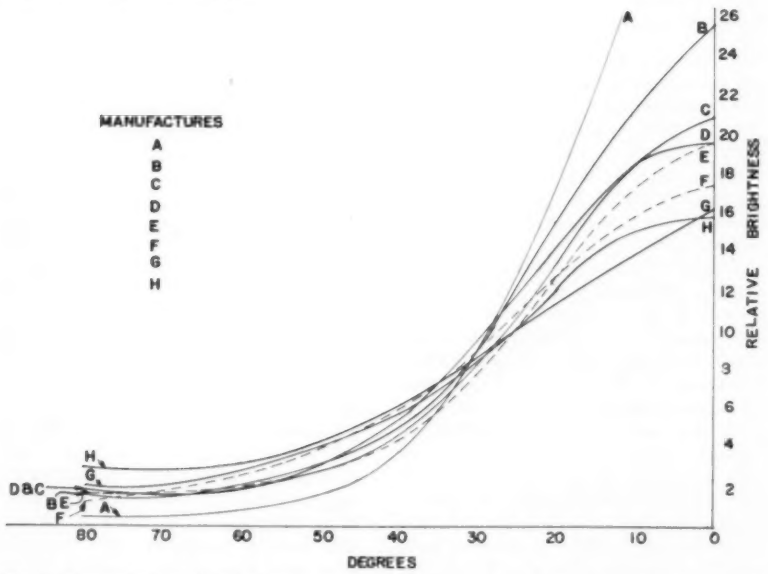


Fig. 9. Comparison of distribution curves taken from various makes of "silver" screens.

Theoretical Screen Performance

When certain assumptions are made, it is possible to compare the possibilities of a theoretical screen and thereby approach practical limitations. Theoretically, lenticular-screen elements can be designed to have uniform brightness through an angle equal to twice the angle made by the radii to the edges in the cross section of the spherical element (Fig. 6). Other factors being equal, the wider the angle, the smaller the gain of the proposed screen. In this paper, gain is defined as the ratio of brightness of a screen sample compared to the brightness of a standard diffuse white screen at the same angle of view. This gain differs from theoretical gain, (defined below), because theoretical gain assumes perfect light diffusion and surfaces which reflect 100% of the light, and these do not exist.

Certain equations have been worked out to give the gain of a lenticular-screen element. In these equations, we may assume all of the light from an element can be so reflected that the flux density will yield a uniform brightness when viewed from any angle defined by the element (Fig. 7). A unit hemisphere is drawn over this element (Fig. 8).[5] The element can be considered a point source of light since it is small relative to the radius of the unit sphere. It is well known that a perfectly diffusing surface reflects light in all directions with uniform brightness, and that the light in any direction, from a small area, is equal to cos Θ times the light reflected at 90° to the surface. In a unit hemisphere any infinitesimal area projected on the base of the hemisphere is equal to the infinitesimal area on the hemisphere times the cosine of Θ. Thus, the light reflected with uniform brightness through any solid angle, or area on the unit hemisphere, is proportional to the projection of that area on the base of the unit hemisphere.

When all the reflected light is confined to a limited area, defined by the angles in Tables I-III, the gain over a perfectly diffusing surface is given by the ratio of the projected area on the base of the unit hemisphere divided into the area of the base of the unit hemisphere. For example: the area of the base of a unit hemisphere is the area of a circle, πR^2. Since R = 1 in a unit hemisphere, the area is π. The radius of the projected circular area in Fig. 8 is sin Θ, so that the area is $\pi \sin^2 \Theta$. For a screen with a uniform circular distribution out to angle Θ, the gain is:

$$G = \frac{\pi}{\int_S ds} \tag{1}$$

$$G = \frac{\pi(1)^2}{\pi \sin^2 \Theta} = \frac{1}{\sin^2 \Theta} \tag{2}$$

where:

G = theoretical gain;
ds = elemental area on the base of the hemisphere;
S = total area on the base; and
Θ = angle measured from a normal to screen elements.

This formula assumes that the integrated total reflection of the lenticular screen surface reflects as much light as does a standard white screen, or magnesium carbonate. When the total reflection of the surfaces is known, it can be incorporated into the formula, as follows:

$$G = \frac{\rho_2}{\rho_1 \sin^2 \Theta} \tag{3}$$

where:

ρ_1 = total reflection of standard screen or magnesium carbonate; and
ρ_2 = total reflection of proposed screen surface.

Note that the higher the total reflection of the proposed screen surface, the higher the gain of a screen with Θ constant.

Another equation can be used to obtain the gain of a screen when the distribution is rectangular.

$$G = \frac{\rho_2 \pi}{4 \rho_1 \sin \alpha \sin \beta} \tag{4}$$

where:

α = horizontal angle; and
β = vertical angle.

This equation is true when: $4 \sin \alpha \sin \beta \leq \pi$.

The total reflection factor can be ob-

Still another equation can be used for the gain of a screen whose distribution is elliptical.

$$G = \frac{\rho_2}{\rho_1 \sin \alpha \sin \beta} \qquad (5)$$

In Tables I, II and III are listed the gains of theoretical screens which will give the audience uniform brightness within the specified angles relative to a 100% diffuse surface. These gains are correct for surfaces of 100% total reflection. The actual gain for any other surface can be determined by multiplying by the ratio of the total reflectances.

Application of Theoretical Results

As stated, the gain formulas assume that all of the light can be concentrated with uniform brightness within the angles selected for the coverage of lenticular elements. In practice, however, the element surface is not completely specular, or smooth, so that some light is diffused beyond the chosen angles. For example, if aluminum paint or plastic with aluminum powder is used for an element surface, considerable diffusion is introduced, causing light to be reflected outside the chosen angles shown in the gain formulas. As a result, the actual gain is lower than the theoretical gain, especially at the edges of the light-reflection pattern.

Application of the gain equations indicates that, theoretically, it is not possible to produce any type of reflective screen which will provide completely uniform screen brightness for all the viewing areas in the average theater and still yield significant brightness gain with reference to a white screen. Since the seats located at the edge of the theater-viewing area involve the brightness of the distribution pattern at the edges of an element, a compromise can be made, if the change in brightness with angle is not too abrupt.

The best compromise is to use an elliptical-pattern screen with more horizontal than vertical distribution, and gradually to decrease the gain from a little more than a factor of 2 at 0° to a factor of 1 at 50° horizontally and 25° vertically. Screens made with elliptical lenticular distribution patterns provide the best compromise because they appear brighter than any other screen from more of the seats in the average theater.[3,6] The diffusion factor has not been introduced into the gain equations, nor has any complex curved surface which produces anything other than uniform brightness from an entirely specular surface. Therefore, considerable data were obtained by experiment because, if diffusion and complex curve factors were introduced into the equations, the integrations would become unduly involved.

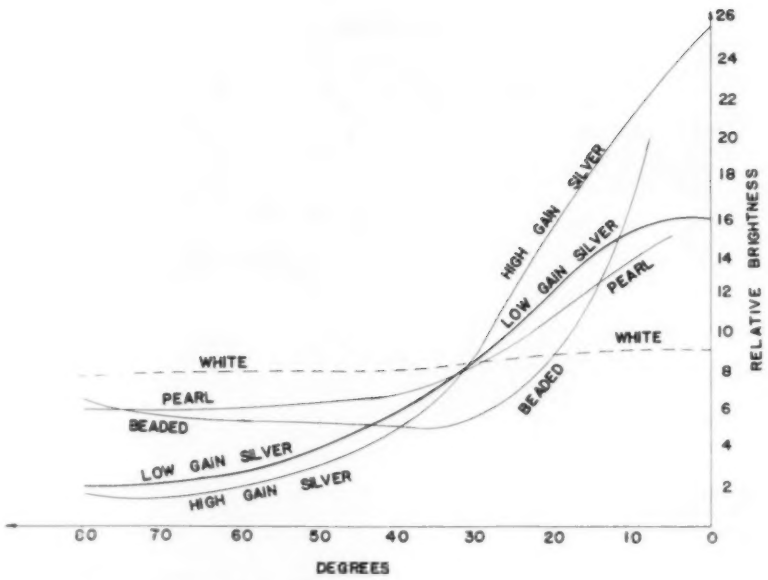


Fig. 10. Typical screen-distribution curves.

Typical Data on Various Types of Screens

At the present time, theater screens can be classed as follows: white; aluminum with random diffusion, often called "silver"; beaded; pearl; and lenticulated with aluminum or pearl surfaces. Data obtained from measurements on typical samples of some of these screens are presented in the accompanying tables and graphs.

Figure 9 shows distribution curves of several different makes of "silver" screens. It is interesting to note that all the "silver" types of screens were about equal to white screens at about 30°, regardless of the amount of diffusion introduced into the surfaces. The screens with high gains in relative brightness at central angles have lower gains at angles beyond about 30°. This type of screen is sometimes called a "high gain" screen; however, it has limited distribution and the brightness changes very rapidly with angle of view. When this type of screen is used, the gain of the screen is often so high in the central angles of the light-distribution pattern that the brightness may be more than five times the brightness at 50°, thereby yielding a picture objectionably dim in some areas relative to brighter areas.

On the other hand, in wide-distribution, "low-gain," "silver" screens, the maximum brightness gain is greatly reduced and does not have the necessary brightness distribution in the horizontal direction.

There has been an unfortunate tendency to make claims for screen performance, based upon a gain value obtained by taking the brightness ratio only at the angle where a particular screen has its maximum brightness. Such claims are usually misleading, because these angles are not as a rule specified, and since gains at other angles are not included, no true evaluation of the screens' capabilities is possible.

With the aid of the integrating sphere, a sample with the highest totally reflecting surface can be chosen for making a screen. Figure 10 shows the typical "silver" screens compared to typical white, beaded and pearl screens. The relative brightness values between ordinates in Figs. 9, 10 and 11 are comparable. The pearl type of screen is made with a coating of essence of pearl over a white base, thereby adding a specular component which can increase the gain of a screen in the central portion of the reflection pattern.

Glass-beaded screens have two properties which make them unsuitable for most theater installations. These beaded surfaces have their maximum reflection in the direction of light from the projector, thereby providing the orchestra seats, especially toward the front of the theater, with low screen brightness, relative to maximum screen brightness. Also, the light distribution pattern of a beaded screen is so narrow and the slope of the curve so steep that this type of screen is unsuited for use in the average theater.

So-called flat white, or white, screens have already been commented on, but because their reflection pattern is almost completely diffuse and their total reflection is high, relative to the incident light, it appears that little increase in "gain" may be expected in future screens of this type. Some white screens have a specular surface which is often embossed with patterns to scatter the specular reflections to keep gain low at the center of the reflection pattern.

screen about the projection distance does

——— WHITE (BEADED AND PEARL SIMILAR)

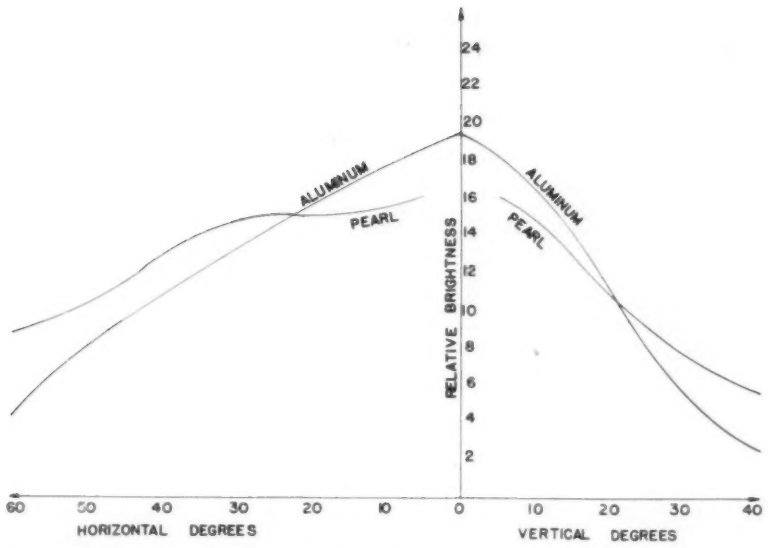


Fig. 11. Typical lenticular screen-distribution curves.

Spectacular gains in picture brightness could be made if a practical way could be found to amplify light, so that more light is produced than is incident upon a screen, thereby making possible the use of small projectors. Unfortunately, at the present time, such a screen does not exist for theaters.[7]

Two types of surfaces, aluminum and pearl, have been used successfully for lenticular screen surfaces (Fig. 11). The specular reflection of these surfaces can be controlled by lenticulation. When this is done, as indicated in the theoretical discussion, so as to provide the maximum gain to the maximum number of seats in the average theater, the distribution pattern is elliptical and the relative brightness readings are indicated along the major or horizontal axis, and the vertical or minor axis of the ellipse.

For reference purposes, a magnesium carbonate block was used to standardize the goniophotometer with the following relative brightness readings:

Angle	$MgCO_3$
0°	10.0
10	9.9
20	9.8
30	9.7
40	9.6
50	9.5
60	9.2
70	9.1
80	9.0

Tables IV–VII present typical relative-brightness readings at angles measured from a perpendicular to the face of a perforated screen sample when normally illuminated.

Table IV. White Screens.

Angle	A	B	C	D
0°	8.4	9.3	8.1	8.9
10	8.4	9.1	8.1	8.9
20	8.2	8.2	8.0	8.6
30	8.0	7.7	7.8	8.2
40	8.0	7.3	8.0	8.1
50	7.8	7.0	7.9	7.9
60	7.6	6.8	7.8	7.9
70	7.6	6.5	7.6	7.8
80	5.3	5.9	7.4	7.6

Table V. Beaded and Pearl Screens.

Angle	Beaded	Pearl A	Pearl B
0°		15.0	19.5
10	16.3	13.6	17.4
20	8.2	10.7	13.5
30	5.5	8.2	9.2
40	5.3	6.7	6.7
50	5.3	6.4	5.6
60	5.2	6.2	5.0
70	5.6	6.2	5.0
80	6.5	6.0	5.0

Table VI. Silver Screens (Aluminum-Surfaced).

Angle	A	B	C	D	E	F	G
0°	37.7	25.5	20.8	19.4	18.1	16.0	15.8
10	31.2	20.6	18.4	17.0	15.7	13.9	15.3
20	17.4	15.6	13.3	12.3	12.7	10.5	12.0
30	9.3	8.9	8.1	7.6	8.8	8.5	8.7
40	3.8	5.0	4.7	4.5	6.0	6.1	5.9
50	1.7	3.1	2.8	3.0	3.9	4.4	4.1
60	1.0	2.1	2.0	2.3	2.8	3.1	2.9
70	0.6	1.4	1.8	2.0	1.6	3.0	2.0
80	0.6	1.6	1.8	1.8	1.4	3.0	2.0

The total reflection factor can be obtained from an integrating sphere as described. Up to the present time, painted aluminum, or plastic with aluminum powder, types of screen surfaces do not equal reflection values of other types of screen surfaces, such as the white, beaded and pearl types of screens. Evaporated aluminum, aluminum foil, or other specular surfaces of high total reflection could be used for lenticular screens, if cost and uniformity problems could be solved.

The following total reflection readings were found to be typical of unperforated screen sample surfaces measured relative to magnesium carbonate:

Type of screen surface	*Typical total reflection readings*
White	91%
Beaded	90
Pearl	90
Aluminum paint or plastic	73
Evaporated aluminum or aluminum foil	91

Washout Measurements

Several types of screens were curved until they formed segments of arcs from approximately 0° to 110°. Brightness readings of the shadow areas on the screen surface became higher as the screen was more deeply curved, indicating the limit of curvature for any type of screen (Fig. 12). The illumination around the spots was 11 ft-c, the screens were 54 in. wide and curved to a depth, or sagitta, of 0, 3 in., 6 in., 9 in. and 14 in., which corresponds to a 54-ft screen curved to a depth, or sagitta, of 3 ft, 6 ft, 9 ft and 14 ft. From observations, it appeared that if the brightness of the spot on the screen exceeded about 0.05 ft-L, some projected pictures would begin to suffer objectionable loss of contrast.

Using arrangement shown for obtaining washout measurements, data were obtained and curves were drawn connecting the points or angles to show the amount of change of washout with the angle of view of the center and side spots. These curves show that washout increases about the same amount from all angles of view when white and similar screens are curved. For lenticular and other specular types of screens, washout depends upon the angle of view. It should be pointed out that, for the average theater, curving a lenticular

Table VII. Lenticular.

Angle	Aluminum Surface		Pearl Surface	
	Horizontal	Vertical	Horizontal	Vertical
0°	19.3	19.3	16.0	16.0
10	17.3	16.4	15.5	14.7
20	15.2	11.0	15.0	10.9
30	13.5	5.5	14.7	7.7
40	11.0	2.7	12.8	5.9
50	8.0	1.7	10.3	5.2
60	4.3	1.5	8.7	5.1
70	2.0	1.1	6.1	5.0
80	1.6	1.0	5.8	5.0

screen about the projection distance does not cause even as much washout as the unobjectionable amount caused by curving a white screen to the same depth.

Composite Screens

Earlier in this paper, the use of composite screens was mentioned as a means of comparison which eliminated many subjective errors of judgment. When viewing samples, the observer should keep in mind the characteristics of the best type of screen surface. It will then be possible to make a more intelligent judgment as to the best screen surface for most theaters. As previously stated, the lenticular screen was developed with the objective of getting a brighter picture to more of the theater seating area. The lenticular screen appears brighter throughout a wider viewing angle than the ordinary "silver" (or aluminum) type of screen, because it has wider light distribution and, in addition, is brighter than the white or pearl screens, except for angles beyond about 50°. Also, it has an acceptable screen-brightness ratio of high-to-low screen brightness as viewed from the audience.

Depolarization and Picture Definition

For optimum results with stereoscopic presentation, it is essential that the screen be of a type which does not depolarize the projected pictures. The following simple test to determine the extent of depolarization was employed. Screen samples were illuminated with polarized light and then examined from various angles through a piece of Polaroid crossed to give minimum light transmission. Results of these tests showed that the aluminum-surfaced lenticular screen produced the least depolarization. "Silver" types with less diffusion were better than those with more diffusion. The pearl, beaded and white types depolarized light to such an extent as to be unsuitable for 3-D pictures based on polarization.

A further interesting effect of a screen's surface is the increase in visual contrast and apparent definition when a picture is projected upon a lenticulated aluminum surface, as compared to projection upon a diffuse white surface. Tests made by varying the brightness, focus, etc., of a picture on both a white and a lenticulated aluminum-surfaced screen indicate that, when other factors are kept constant, the picture on the lenticulated aluminum screen always appears to have more contrast and definition. This effect is still under continued investigation and it is hoped that it will be the subject of a future paper.

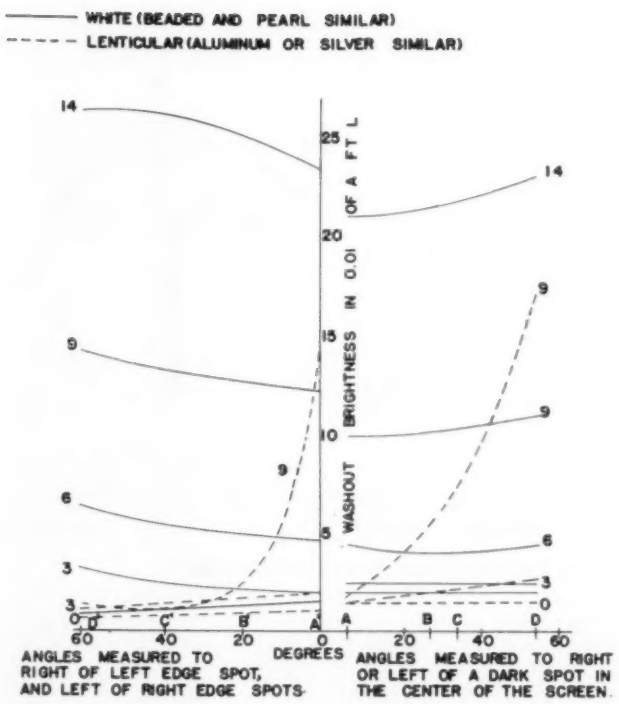


Fig. 12. Screen washout brightness readings of shadowed spots from various points around curved screens.

Tilted Lenticular Screen Patterns

Screens of the lenticular types have been made to compensate for projection angles of from 15° to 20°. These screens have a tilted element and, when tested with a goniophotometer, a displaced distribution pattern will be obtained. The pattern, in other respects, will be identical with the elliptical distribution pattern previously described.

Conclusions

New screen surfaces should be tested by the comparison procedures described. Such tests indicate that a properly installed lenticular screen with high total reflection and an elliptical light-distribution pattern, having a gain of about 2 in the central portion and then falling off gradually to 1 at 50° on each side of a perpendicular to the sample and 25° in the vertical, will give a better picture to more people in the theater than any other type of available screen.

I should like to thank all who have helped in this paper, and especially my associates, Herbert E. Bragg and Otto A. Wantuch, and Albert B. Hurley of the Hurley Screen Company.

References

1. F. B. Berger, "Characteristics of motion picture and television screens," *Jour. SMPTE, 55:* 131–146, Aug. 1950.
2. L. D. Clark, "Picture quality of motion pictures as a function of screen luminance," *Jour. SMPTE, 61:* 241–247, Aug. 1953.
3. G. Gagliardi, "Equipment required for a well-lighted picture," *Motion Picture Herald, Better Theatres, 206, No. 10:* 20–21, Mar. 9, 1957.
4. E. W. D'Arcy and G. Lessman, "Objective evaluation of projection screens," *Jour. SMPTE, 61:* 705–706, Dec. 1953.
5. P. Moon and D. E. Spencer, *Lighting Design,* Addison Wesley, Cambridge, Mass., 1948.
6. G. Gagliardi, "What light gain means to actual screen performance," *Motion Picture Herald, Better Theatres, 203, No. 6:* 18–31, May 12, 1956.
7. B. Kazan and F. H. Nicoll, "Solid-state light amplifiers," Paper at Optical Society of America Meeting in New York, Mar. 8, 1957.

Discussion

Richard H. Ranger (Rangertone, Inc.): I have the feeling that, without any question, the lenticular is more brilliant. It may be just subjective, but the white seems to have more contrast. Do you have figures that show that that isn't true?

Mr. Hurd: We don't have the figures. We are investigating that. There's been some discussion about that among our own and other people, especially when ambient conditions are higher than they actually were when you viewed this screen, the resulting idea being that the lenticular screen will give higher definition and contrast. Under our conditions of viewing most people observe the higher definition in the aluminum screen over the pearl or white.

elements in the plastic sheets formed

Minimizing the Effects of Ambient Light on Image Reproduction

By G. L. BEERS

One of the important factors in determining the quality of either a television or motion-picture image is the ambient light to which the image is subjected and the effect of this light on the reproduced picture. Some of the means which have been employed to minimize the effects of ambient light on picture reproduction are reviewed. A method has been developed which under favorable conditions has produced startling results in permitting the reproduction of both television and motion-picture images under adverse ambient-light conditions. The paper describes this method and gives experimental data illustrating its effectiveness under typical conditions. Some of its limitations are indicated.

One of the factors which greatly influences the quality of a television or motion-picture image is the ambient light to which the reproduced image is subjected. If black-and-white images are reproduced in a conventional manner and the ambient light is increased from a negligible value, a reduction in image contrast occurs and ultimately a point is reached where the image is completely indistinguishable. If the image is in color, an additional effect is observed in that all color values are degraded and at relatively low ambient-light values saturated colors become pastel and washed-out in appearance.

A method has been developed which under favorable conditions has produced startling results in permitting the reproduction of both television and motion-picture images under adverse ambient-light conditions. It is the purpose of this paper to describe this method and to discuss experimental data illustrating its effectiveness under typical conditions.

Some of the Means Previously Used or Considered

The degradation in reproduced television images by ambient light is brought about by the fact that the phosphor screen in a television picture tube reflects light. Accordingly, the face of a picture tube has a certain brightness-value when no picture is being reproduced and this brightness-value is a function of the ambient light. An obvious solution to the television problem is a phosphor screen which does not reflect light and which would appear black under all ambient-light conditions. Unfortunately, such a phosphor screen has not been developed.

Two other alternatives may be employed: One is to increase the picture-highlight brightness to the point where the ambient light produces minimum effect; and the other is to prevent the ambient light from reaching the face of the picture tube. Both alternatives have practical limitations.

Presented on October 11, 1956, at the Society's Convention in Los Angeles, Calif., by Dr. G. L. Beers, Bldg. 2-8, Radio Corp. of America, Camden, N.J.
(This paper was received on January 10, 1957.)

Increased Picture Brightness

It has been said that lumens in color is a very expensive commodity and this is certainly true in the case of either television or motion-picture images. For a given picture-tube structure, increased picture-brightness can be achieved either by improved phosphor efficiency or higher beam power which is frequently obtained by increasing anode voltage. Although the search for phosphors with substantially higher efficiency continues, only moderate improvement has been achieved in recent years. Television-receiver and picture-tube costs go up so rapidly when the anode voltage is increased above 25 kv that this approach to increased brightness generally has been considered impractical.

Certain tube structures are inherently capable of higher brightness through more efficient beam utilization, but these structures frequently require expensive parts or manufacturing techniques and the increased brightness is often obtained at a sacrifice in picture sharpness and contrast.

It is expected that, in time, the means will be found to produce substantially brighter television pictures in color without excessive cost.

Increased brightness alone, however, cannot provide ideal results under adverse ambient-light conditions. For example, measurements have shown the face of a picture tube in a color television receiver under the ambient-light conditions frequently encountered in the home in daylight or in lighted showrooms in stores to have a brightness of at least 5 ft-L when the receiver is turned off. If the picture tube were capable of a highlight brightness of 500 ft L, a contrast range of 100 to 1 could be obtained in the reproduced picture. If in viewing a picture under these conditions, however, a black object such as a telephone or ash tray is located near the receiver so that it is included in the observer's angle of vision, a black in the reproduced picture would necessarily have a brightness-value of at least 5 ft-L and in comparison with the black telephone or ash tray would not appear totally black, but would have instead a dark gray appearance.

Neutral Density Filters or Gray Glass

The second alternative, that of preventing the ambient light from reaching the picture tube screen, has been extensively used in black-and-white television receivers. Gray glass is employed in the face of the picture tube and sometimes in the shatterproof glass located between the picture tube and the viewer. This provides a gain in picture-contrast ratio because ambient light must travel through the glass twice to reach the phosphor screen of the picture tube and be reflected back to the observer; whereas the light produced by the electron-stream bombardment of the phosphor screen passes through the gray glass but once. Thus an improvement in contrast is achieved at a sacrifice in maximum picture brightness and the effect of the ambient light on the quality of the reproduced picture is reduced. The higher the brightness-capability in the picture tube, the greater the absorption which can be used in picture-tube face plates to minimize the effects of ambient light.

It is, of course, essential that the brightness-capability of the picture tube be great enough to produce with the degree of absorption employed, a picture brightness which is higher than the brightness of other areas within the viewing angles of those watching the picture. Unless this is done, even though a high contrast range is maintained in the picture, the total light reaching the eye may cause the iris to close to such an extent that the eye is no longer capable of perceiving the range of gradations between light and shade in the picture.

Directional-Viewing Screens for Projected Images

Another method for preventing ambient light from degrading reproduced images is that of employing directivity in the viewing screen. RCA, Eastman Kodak, Philips and others have developed for projection-type television receivers screens whose directional characteristics provide considerable protection against ambient light. These screens are limited in viewing angle and have a gray to black appearance under relatively high ambient-light conditions with no picture projected. Those with the highest gain

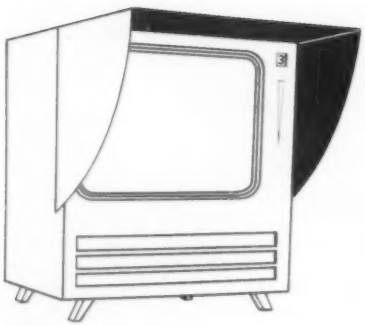


Fig. 1. The shadow box.

and the greatest protection against ambient light are generally of the translucent type employing special lens systems which are frequently difficult to produce with uniform optical properties over a large picture area. They have not been used extensively since as yet projection-type television receivers have not come into general use.

Directional-Viewing Devices of the Shadow-Box Type

Another directional means for preventing ambient light from degrading a visual image is the use of a shadow box, shown in Fig. 1, which surrounds the entire picture area. The angle through which the picture can be viewed is determined by the dimensions of the sides of the box and the spacing between them. The wider the viewing angle, the less protection provided by the shadow box against ambient light, so the choice of viewing angle is generally a compromise between the degree of ambient-light protection desired and the restriction on locations from which the picture can be viewed. Shadow boxes have not been used extensively, probably because they are generally unsightly and give disturbing shadow effects when a source of light is near the cutoff angle of the box. Under this condition a shadow is cast across the picture area and, although part of the picture is protected against the light source, part is degraded by it.

A modification of the shadow-box idea was proposed by G. Zindel, Jr., in 1942 and is described in U.S. Patent 2,388,203. The Zindel arrangement consisted of two plastic sheets having thin, opaque, parallel ribbon-like elements embedded therein. These sheets of material constitute, in effect, a venetian blind with the slats separated by transparent plastic material. According to the patent, two of the sheets, one in front of the other, were placed over the face of a cathode-ray tube with the opaque ribbon-like elements of one at right angles to those of the other. This was done "so that the screen of the tube could be made clearly visible without the necessity of employing a hood." Each of the small areas between pairs of vertical and horizontal opaque elements in the plastic sheets formed, in effect, a small shadow box. The disturbing shadow effects of the large shadow box will not be apparent in the Zindel arrangement if the unit areas between pairs of parallel opaque elements in the plastic material are small enough so that the eye cannot distinguish the variation in brightness across these small areas. The limitations of the Zindel screen will be mentioned later.

The Ambient Light Problem in Motion Pictures

The ideal motion-picture screen is one which would appear black when subjected only to ambient light and which would reflect efficiently the light of an image projected upon it.

The degradation of picture quality by ambient light in motion pictures is even more serious than in television. Not only is it very difficult to increase brightness-values, but the very nature of the motion-picture system requires that the projection screen on which the picture is reproduced be an efficient light reflector. Thus the motion-picture screen is inherently a more efficient reflector of ambient light than the screen of a television picture tube. The ambient-light levels which can be tolerated in motion pictures are substantially below those generally used in viewing television images.

Rear-projection screens with directional characteristics such as those mentioned for television receivers provide the possibility of minimizing substantially the effects of ambient light on motion-picture reproduction. Although rear projection has been used in the Translux Theaters, the additional space required when the projector is on the opposite side of the screen from the audience has prevented its extensive use by the motion-picture industry. A moderate degree of protection against ambient light has been obtained with small front-projection screens measuring about 30 in. × 40 in. and employing lens systems.

Directional-Viewing Devices as a Means for Minimizing Ambient-Light Degradation

In considering the ambient light problem, it was soon realized that a viewing device which would prevent light from sources outside a predetermined viewing angle from reaching the surface on which a television or motion-picture image is reproduced would substantially reduce the effects of the ambient light on the reproduced image. In the auditorium, the classroom, or the home, the viewing angle occupied by the audience generally represents only a fraction of the total area from which light can reach the viewing screen. Since the audience is either seated or standing, the vertical viewing angle is considerably narrower than the horizontal. If a directional-viewing device with satisfactory horizontal and vertical viewing angles to accommodate the audience can be so placed that the major sources of ambient light are located outside these viewing angles, it should be possible to tolerate relatively high values of ambient light without serious degradation to a reproduced image.

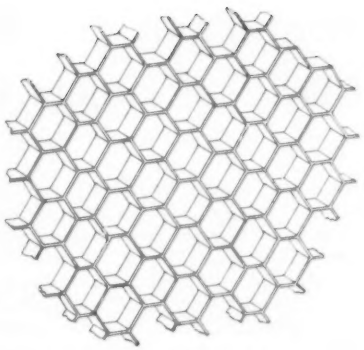


Fig. 2. The honeycomb.

Requirements for a Satisfactory Directional-Viewing Device

Our study of the ambient-light problem from the directional viewing device standpoint culminated in establishing the following requirements which a satisfactory device should meet.

(1) The device should provide as high a picture brightness as possible over the desired viewing angle.

(2) Light from all sources outside the viewing angle for which the device is designed should be prevented from reaching the surface on which the image is reproduced.

(3) Polished surfaces capable of producing specular reflections must be avoided. The plastic sheets in the Zindel arrangement are likely to cause such reflections.

(4) Structures which are particularly susceptible of producing interference effects with the scanning lines of a television image should not be used. The opaque elements which form perpendicular lines in the Zindel viewing-screen are a potential source of interference effects with television images.

(5) If possible the directional viewing device should be suitable for either directly viewed or projected television images and motion pictures.

The Honeycomb Screen as a Directional-Viewing Device

In our quest for a directional-viewing device, we came to an abrupt realization that certain cellular structures having thin opaque walls had characteristics consistent with the foregoing requirements. The directional characteristics of a cellular structure are determined by the length, width and depth of the individual cells. An investigation of

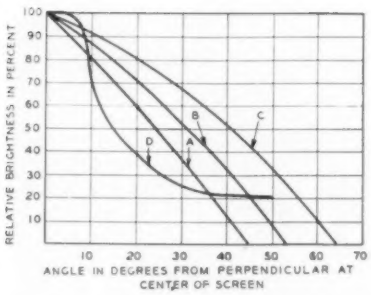


Fig. 3. Directional characteristics of the honeycomb screen as a function of the cell depth.

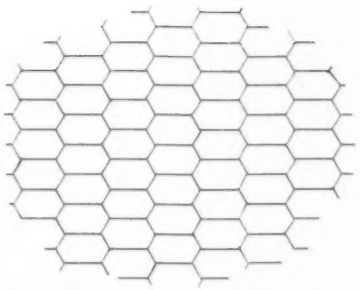


Fig. 4. Honeycomb with different directional characteristics in the horizontal and vertical planes.

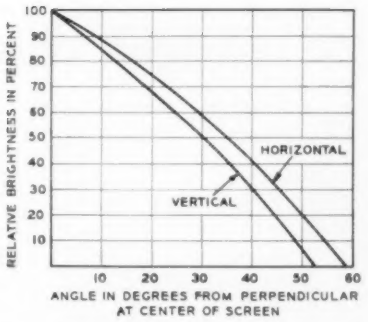


Fig. 5. Directional characteristics of honeycomb screen similar to Fig. 4 but with less difference between the horizontal and vertical cell dimensions.

several cellular materials showed that a honeycomb structure with light-absorbing walls, as illustrated in Fig. 2, possessed the following desirable characteristics.

(1) The honeycomb screen lends itself to manufacturing processes which permit it to be made with very thin walls thus providing high light transmission through the structure.

(2) The walls of the structure can be made light-absorbent and thus prevent light from sources outside a desired viewing angle from reaching the surface on which the image is reproduced.

(3) The viewing angle provided by such a screen can be controlled readily by changing the depth of the screen in relation to the spacing between the cell walls. Different horizontal and vertical viewing angles can be achieved by varying the width of the cells in relation to their height.

(4) The directional properties of the screen are achieved without the use of polished surfaces and the screen does not give specular reflections. Specular reflections from the face of the picture tube, due to light sources outside the viewing angle of the screen, are eliminated or substantially reduced.

(5) The edges of the honeycomb structure do not form straight lines in any direction and interference effects with television scanning patterns are minimized.

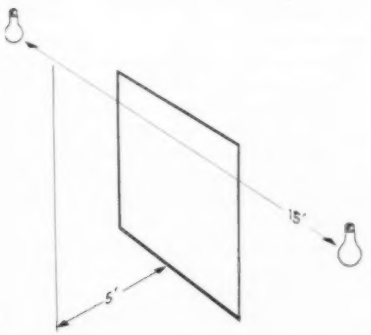


Fig. 6. Arrangement of screen and lights to give optimum results with screens having characteristics similar to those of Fig. 3.

(6) This type of directional-viewing device lends itself equally well to television reproducers of either the directly-viewed or projection types and to motion pictures.

Early in our investigation of honeycomb structures as directional-viewing screens, we obtained samples of material ranging in cell sizes from $\frac{1}{8}$ in. to $1\frac{1}{2}$ in. Experiments with these materials showed that with cell dimensions giving a reasonable viewing angle, they could provide an improvement in contrast ratio from 3-to-1 to 20-to-1 under typical ambient-light conditions.

Directional Properties of the Honeycomb Viewing Screen

Figure 3 shows the directional characteristics of the $\frac{1}{8}$-in. cell material illustrated in Fig. 2. Curves A, B and C are the characteristics obtained with cell depths of $\frac{1}{8}$ in., $\frac{3}{32}$ in. and $\frac{1}{16}$ in., respectively. These curves show relative brightness or light transmission in per cent as a function of the angle in degrees from a perpendicular to the screen. For comparison, curve D shows the variation in brightness as a function of viewing angle of a typical beaded screen used for the projection of slides and movies in the home. It is seen that the angle within which a brightness-value of at least 50% is obtained is much greater for the honeycomb screen represented by curve B than the corresponding angle for the beaded screen. The loss in light at 0° for the three screens giving curves A, B and C was approximately 7%.

Figure 4 shows a honeycomb structure with different horizontal and vertical cell dimensions to provide different horizontal and vertical viewing angles. The curves in Fig. 5 are the horizontal and vertical characteristics of a screen with only a slight difference between the horizontal and vertical cell dimensions.

Contrast-Ratio Improvement

Screens represented by curves A, B and C were tested on television receivers and motion-picture screens in a wide variety of locations. One of the practical advantages of screens of this type is the ease with which their effectiveness for any ambient-light condition can be determined either subjectively or by measurement. If a piece of the screen material is placed directly in front of the face of a picture tube or motion-picture screen when no picture is reproduced, the extent to which the image-reproducing surface appears darker indicates the contrast improvement to be expected. Brightness measurements with and without the screen in place will give a ratio indicating the maximum improvement which can be obtained under the existing ambient-light conditions. This improvement, of course, is contingent upon the reproducing system being capable of producing an image with a contrast ratio sufficiently high to take advantage of the increased contrast range permitted by the screen.

Measurements made on both television receivers and motion-picture screens under typical ambient-light conditions showed potential improvements in contrast range of from 3-to-1 to as great as 20-to-1. Figure 6 illustrates in a general way the conditions which permit contrast-ratio improvements as high as 20-to-1 to be obtained with these directional-viewing devices. With the lights and motion-picture screen located as shown in Fig. 6 which gives an angle of approximately 60° between the lights and a perpendicular to the screen, the follow-

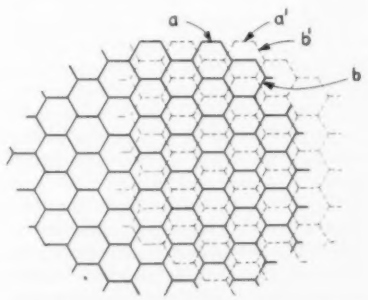


Fig. 7. Combined horizontal and vertical scanning action from horizontal movement of honeycomb screen.

nated by the screen and cannot be seen

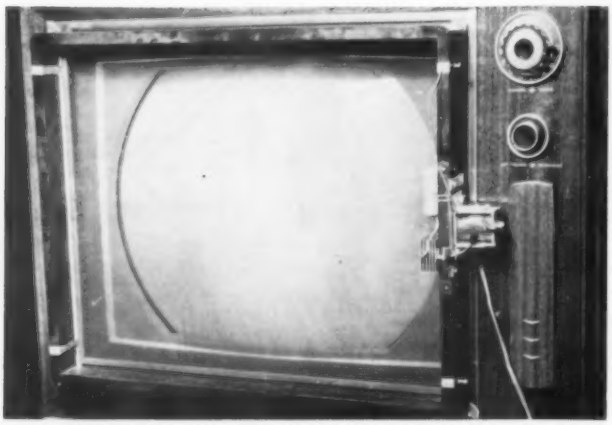


Fig. 8. Experimental oscillating honeycomb viewing screen with a solenoid driver.

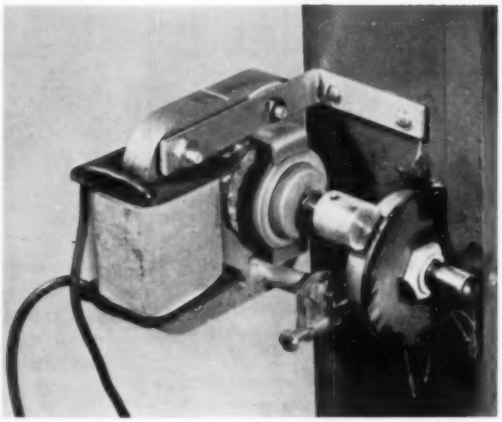


Fig. 9. Phonograph motor driving unit for oscillating screen.

ing brightness measurements were obtained:

Motion-picture screen alone . . 2.0 ft-L
Motion-picture screen in combination with directional-viewing device giving curve A in Fig. 3 . . . . . 0.1 ft-L
Motion-picture screen in combination with directional-viewing device giving curve B in Fig. 3 . . . . . 0.2 ft-L

Under the conditions of Fig. 6 improvements in contrast ratios of approximately 20-to-1 and 10-to-1 are possible through the use of these screens. As one would expect, contrast range improvements of 10- or 20-to-1 can make the difference between having a picture and not having one.

Relationship of Cell Dimensions to Picture Detail

Tests with the honeycomb materials confirmed our opinion that the cell size should be at least as small and preferably smaller than the finest detail in the image being reproduced. With a 21-in. television picture tube, it was apparent that the $\frac{1}{8}$-in. cell size was too large. Arrangements were made with Hexcel Products, Inc., of Oakland, Calif., to develop screens having cells approximately $\frac{1}{32}$ in. $\times$ $\frac{3}{64}$ in. Screens with cells of these dimensions were produced but they were not entirely satisfactory, first, because these screens could not be produced with uniform cell dimensions over a large area such as 24 in. $\times$ 24 in., with available materials, and secondly, because when the picture on a tricolor tube was viewed through this screen, an objectionable moire pattern was seen. The relationship between the size of the openings in the screen and the area occupied by each group of three phosphor color dots was such that an interference pattern resulted because in certain areas only two of the three dots could be seen. Such an interference pattern will be observed as variations in brightness, even though only one color is being reproduced. If it were possible to make a screen with cell dimensions substantially smaller than the size of a phosphor dot in the tricolor tube, this difficulty could be avoided. Alternatively, should the picture size be increased substantially from the 21-in. size used in this investigation, the minimum cell size necessary to avoid such tricolor tube interference effects would be correspondingly increased. This problem is, of course, not encountered with motion-picture screens.

Another factor relating to cell size, however, is important in both television and motion pictures. Unless the cell size is smaller than the finest detail in the reproduced picture, some of the information in the picture is lost if viewed through a directional screen of the cellular type at an angle from a perpendicular to the screen. Here again, if the picture size is large as is generally the case in motion pictures, there is little difficulty in meeting this requirement. In the case of television, however, taking a 21-in. picture tube for example, the problem is analogous to that of the interference difficulty previously mentioned. A cell size that is satisfactory from the moire or interference standpoint will also be satisfactory from the standpoint of no loss of detail when viewing the picture at any position within the viewing angle of the screen.

The Oscillating Honeycomb Screen

A means has been devised for overcoming the requirements of small cell size to avoid the interference effects and loss of information or picture detail just discussed. By moving the honeycomb screen back and forth in a horizontal direction at the relatively slow rate of, for example, 16 cycles/sec, and through a distance comparable to the width of a cell, the entire picture area is effectively scanned with the following important advantages:

(1) The moire difficulty discussed in connection with the tricolor tube is overcome. Since the screen wall, which blocks the light from any particular phosphor dot, moves back and forth, the blocking action occurs only momentarily and is alike for each phosphor dot so that the viewer obtains the proper light values from all of the phosphor dots.

(2) All the information in the picture can be viewed from any position within the horizontal or vertical viewing angles for which the screen is designed, since the honeycomb structure has an important advantage in that a horizontal movement of the screen provides in effect both a horizontal and a vertical scanning component which enables light from each minute portion of the picture area to reach the viewer.

(3) The structure of the screen itself is not visible to the viewer even at relatively close viewing distances.

(4) All the capabilities of protection against ambient light of the stationary screen are retained.

Figure 7 illustrates the combined horizontal and vertical scanning action which results from a slight horizontal movement of the honeycomb screen. The solid lines show an outline of the cells in a small area of the screen. Assuming that the screen moves in a horizontal direction until cell **a** occupies the position **a′**, it will be noted that the outline of the cells now is the same as if the screen had moved in a vertical direction so that cell **b** occupied the position **b′**. Thus it will be seen that a horizontal movement of the screen has also produced the equivalent of a vertical movement of the screen so that the entire picture area is effectively scanned and the cell-size limitation on picture detail is overcome.

An experimental directional honeycomb viewing screen of the oscillating type is shown in Fig. 8. This screen employed $\frac{1}{16}$-in. cells having a cell depth of $\frac{3}{64}$ in. The amplitude of movement used with this screen was approximately $\frac{1}{16}$ in. The screen in this arrangement was supported at the four corners by narrow flat springs which permitted it to move in a

the face of the picture tube through the

ing screens for radar display devices

proof glass at the top of the picture area.

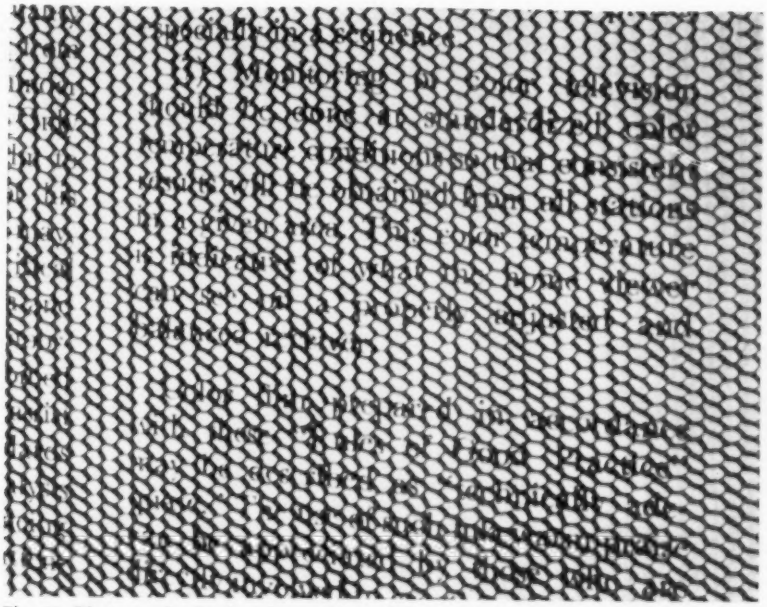


Fig. 10. Photograph of printed page viewed through stationary honeycomb screen.

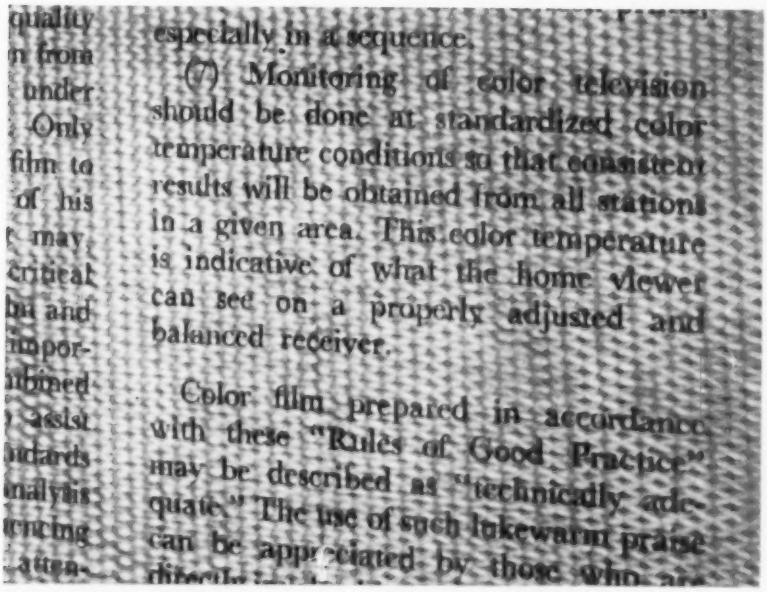

especially in a sequence.
(7) Monitoring of color television should be done at standardized color temperature conditions so that consistent results will be obtained from all stations in a given area. This color temperature is indicative of what the home viewer can see on a properly adjusted and balanced receiver.
Color film prepared in accordance with these "Rules of Good Practice" may be described as "technically adequate." The use of such lukewarm praise can be appreciated by those who

Fig. 11. Photograph of printed page viewed through oscillating honeycomb screen.

horizontal direction. A solenoid driving system was used to oscillate the screen. Another driving arrangement is shown in Fig. 9. It consists of an eccentric wheel in contact with one edge of the screen and rotated by a small phonograph motor.

To illustrate the effect on picture detail when viewing an image through the screen at an angle, a page of the SMPTE *Journal* was photographed through the screen at an angle of approximately 25° to the normal to the screen. Figure 10 shows the result with the screen stationary; and Fig. 11, with the screen moving. Although these photographs leave something to be desired as contrasted with viewing the two conditions directly, they nevertheless show the marked improvement in picture detail obtained with the moving screen.

Figure 12 is a photograph of a color-bar pattern reproduced on a tricolor tube and viewed through the experimental oscillating screen with the room lights turned on. Figure 13 shows the same color-bar pattern under the same lighting conditions with the experimental screen removed from the receiver. The marked degradation in the color values and the reduction in contrast due to the ambient light are apparent from a comparison of these photographs. The specular reflections from the lights, quite visible in Figure 13, were eliminated by the screen and cannot be seen in Figure 12. Brightness measurements showed a 6-to-1 improvement in contrast ratio obtained with the screen. The face of the picture tube without a picture being reproduced had a brightness of 1.0 ft-L. With the screen in front of the tube this value was reduced to 0.16 ft-L.

Subjective Results

The following observations are based on the author's experience with honeycomb directional-viewing devices in a wide variety of experimental installations.

The use of a directional-viewing device to protect the face of the picture tube in a television receiver against ambient light, and the proper use of ambient light, particularly as background illumination for the receiver, result in more pleasing picture reproduction with less eyestrain. If a background brightness value of approximately $\frac{1}{10}$ the average picture highlight is used, the subjective result is an apparent increase in picture contrast over viewing the same picture in total darkness. The illuminated background provides a reference-brightness level for the eye with the picture highlights going above this value and the dark areas going below.

Observations and measurements made on seven television receivers located throughout a large department store showed that a viewing screen having directional characteristics in both horizontal and vertical directions similar to curve B in Fig. 3, provided improved picture quality from each receiver. The viewing angle through which the picture could be observed was, of course, limited to the extent shown by curve B. The contrast-ratio improvement contributed by the directional-viewing screen for each receiver location was determined by brightness measurements with the following results:

Receiver location	*Contrast ratio improvement made possible by directional-viewing screen*
1	9.0
2	4.7
3	4.0
4	2.4
5	4.0
6	4.0
7	3.3

Since these receivers had been installed without considering the use of the directional-viewing device, substantially higher contrast-ratio improvements could have been obtained had several of the receivers been relocated. For example, the receiver which gave an improvement of only 2.4 with the directional-viewing device was located near, and facing directly into, a store entrance. Daylight reaching the face of the picture tube gave it a brightness value of 6 ft-L with the set turned off and without the directional-viewing device. Since the major portion of the ambient light on this receiver reached

the face of the picture tube through the viewing angle of the directional screen, it was relatively ineffective. Relocating this receiver could have made the directional screen much more useful.

In the case of motion pictures, similar subjective results have been obtained. Satisfactory picture quality can be achieved through the use of the directional-viewing screen under ambient-light conditions which would have given a totally washed-out picture with a conventional screen. In order to achieve these results, the major sources of ambient light must be located so that they are outside the viewing angle of the directional-viewing screen. Ambient light can generally be used to give a more pleasing picture reproduction, provided the screen is protected against the ambient light so that picture contrast is not degraded.

Figure 14 shows the author demonstrating a honeycomb directional motion-picture screen in a small auditorium in Camden, N.J. This screen* had directional characteristics shown in Fig. 5. The normal lighting arrangement of the auditorium was used with all the lights turned on. The location of the lights made it possible to take full advantage of the directional characteristics of the screen. The screen at the right of the photograph is the motion-picture screen permanently installed in the auditorium. A picture projected simultaneously on both screens gave the results shown in this photograph.

An interesting observation was made during a test of a directional-viewing screen with a theater television system. The projector used in this system produced 15-ft × 20-ft pictures in color. The directional-viewing screen employed in the test was approximately 6 ft × 6 ft and had directional characteristics similar to curve B in Fig. 3. This directional-viewing device was placed over the center area of the 15 ft × 20 ft screen and when 15 ft × 20 ft pictures were projected, a direct comparison between the normal screen and the directional-viewing device was obtained by comparing the picture quality in the center and outside areas. During a test with no ambient light and with a projected picture with relatively large highlight areas, higher contrast was noted in the picture area covered by the viewing device. Sufficient light from the large highlight areas of the picture was reflected by the walls of the room back to the screen. This produced a noticeable reduction in picture contrast in the unprotected portion of the screen. It is the author's opinion that the large curved motion-picture screen will present a serious problem from a picture contrast standpoint.

Subjective tests with directional-viewing screens for radar display devices showed that they gave the expected protection against ambient light insofar as contrast improvement is concerned. These tests, however, emphasized the fact that even though a high contrast ratio is maintained in the image, adequate brightness must also be provided under severe ambient-light conditions. If the image brightness is low and the total light reaching the eye is relatively high, the eye will be unable to perceive the gradations between light and shade in the image even though there is no limitation in image contrast.

Some Practical Considerations in Using Honeycomb Directional-Viewing Devices

The ideal honeycomb directional-viewing device for permanent installation in a television receiver should be of sufficient strength and of sufficiently small cell dimensions to provide adequate protection against picture-tube implosion. It would then be possible to dispense with the shatterproof glass in front of the picture tube, a source of annoying specular reflections. The small-cell-size honeycomb material used in our investigation was made of aluminum foil with a thickness of approximately 0.001 in. This material is not particularly rugged and care must be exercised in its use. A much stronger material would be required to meet the picture-tube implosion requirement. It is understood that honeycomb screens have been fabricated of other materials such as stainless steel, Fiberglas and plastics. At the time of our investigation, we were unable to obtain screens of these materials with cell sizes of $\frac{1}{8}$ in. or less. It is quite possible, however, that screens of one of these materials can be produced to meet the implosion requirement.

If, on the other hand, a receiver is provided with a directional-viewing screen to be used only when severe ambient-light conditions are encountered, as when viewing programs in daylight, a screen arrangement such as illustrated in Fig. 15 can be used. This cabinet design makes it possible to slide the directional-viewing screen back into a recess in the top of the cabinet when not required. This method of storing the screen could be applied equally well to either side of the cabinet.

A simple and inexpensive means of providing a screen which can be attached to and removed from an existing receiver as desired is shown in Fig. 16. Thin flexible members extend from the bottom of the screen frame so that they can be inserted between the bezel and shatterproof glass at the bottom of the picture area. The long flat spring members extending from the top corners of the frame can be bent back till the top edge of the springs can be inserted between the bezel and shatterproof glass at the top of the picture area. On releasing the springs, the screen structure is pulled back against the shatterproof glass and the flat screen-mounting members are completely hidden.

One of the requirements of a directional-viewing screen of the cellular type is that cell dimensions be reasonably uniform throughout the picture area. If this requirement is not met, and if the viewing angle is increased to a point near the cut-off angle of the screen, the variations in cell dimensions will cause certain areas to cut off more quickly than others. This will produce random brightness variations which may be quite noticeable.

The possibility of dust collecting in honeycomb screens has been considered. Our experience has been that screens installed in fixed locations for several months have shown no difficulty from dust collection. It is reasonable to expect that should such a screen collect dust, it could be cleaned with the type of vacuum cleaning equipment used in the home for cleaning upholstery and draperies.

One of the limitations of the honeycomb screens used in our investigation is that they cannot be used to provide roll-up type motion-picture screens. Until a flexible honeycomb material which can be rolled up and which will retain its original shape when unrolled is produced, motion-picture screens employing the honeycomb directional-viewing screen must be of the rigid type. Screens of this type when located where they are subject to accidental damage should be protected by a cover when not in use.

The drive-in theater presents a variety of ambient-light conditions for which a directional-viewing screen may be helpful. Not only do such factors as daylight-saving time influence program schedules, but automobile headlights and moonlight can seriously degrade the picture at night. Curve A in Fig. 17 shows the brightness of a flat screen as a function of time beginning at 7:00 P.M. and continuing until 8:08 P.M. These measurements were taken in August in New Jersey at a location without any nearby obstructions. The screen was facing toward the east. Curve B in Fig. 17 shows the brightness values obtained after a directional-viewing device having a characteristic similar to curve B in Figure 3 was placed over the flat screen surface. The improvement in contrast ratio which the directional-viewing device could contribute under the conditions of this test varied from 3.35 to 1 at 7:00 P.M. to 4.25 to 1 at 7:55 P.M. and 4.15 to 1 at 8:08 P.M. Measurements such as these make it possible to determine the benefit which can be derived from a directional-viewing screen for drive-in theater applications. Honeycomb cell sizes between $\frac{1}{4}$ in. and $\frac{3}{4}$ in. should be suitable for drive-in screens.

* This screen was also used for the demonstration accompanying this paper at the 80th SMPTE Convention at Los Angeles.

oscillating the screen is where you have a very small image and you cannot make the openings

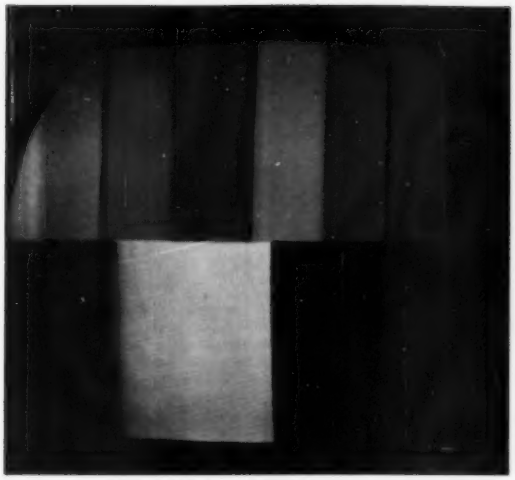


Fig. 12. Photograph of color-bar pattern on color receiver viewed through oscillating screen and room lights turned on.

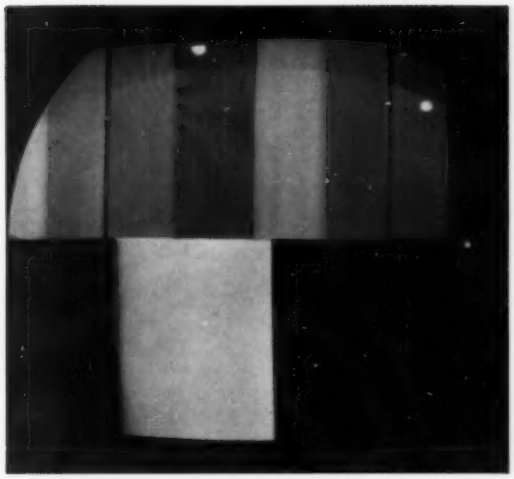


Fig. 13. Photograph taken under conditions of Fig. 12, but oscillating screen removed from receiver.

Fig. 14. Photograph showing comparison between honeycomb and conventional screens with projected picture and high ambient light.

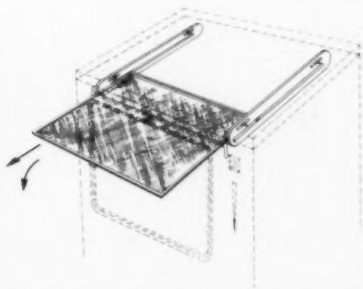


Fig. 15. Television receiver cabinet with recess in top for honeycomb screen.

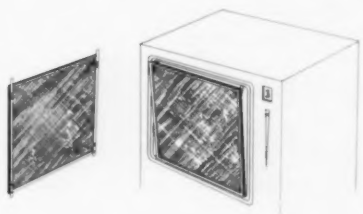


Fig. 16. Detachable honeycomb screen.

Conclusions

A study of the ambient-light problem in image-reproducing systems has led to the following conclusions:

(1) A directional-viewing device which prevents light from sources outside a predetermined viewing angle from reaching the image-reproducing surface can substantially reduce the degrading effects of ambient light on a reproduced image.

(2) A simple honeycomb structure used as a directional-viewing device is capable of producing image contrast-ratio improvements in the range from 3-to-1 to 20-to-1 under typical ambient-light conditions.

(3) The honeycomb directional-viewing device is effective for either directly viewed or projected television images and for motion pictures. It can be used equally well for either front- or rear-projection screens.

(4) An oscillating honeycomb structure has distinct advantages in avoiding the impractical cell dimensions required for a small-size directional-viewing screen.

Acknowledgment

The author wishes to acknowledge the enthusiastic cooperation of F. L. Creager, Superintendent, Model Shop at the David Sarnoff Research Center, Princeton, N.J., in the construction of the several model screens used in this investigation and the assistance of Hexcel Products, Inc., Oakland, Calif., who supplied the honeycomb materials used for these screens.

Discussion

Anon: Is there a specification for the distance between the mosaic and the surface of the screen?

Dr. Beers: As a general rule you would put the honeycomb structure as close to the reproducing surface as possible. It is not critical; we've used the screens several inches away from the reproducing surface as well as practically in contact. The protection against ambient light is the same in either case. There are some secondary effects if there are irregularities in the screen structure. The irregularities will be more noticeable if the screen is spaced away from the surface on which the image is reproduced and the viewer moves his head in a plane parallel to the screen.

George Lewin (Army Pictorial Center): Do I

A Color Schlieren System for

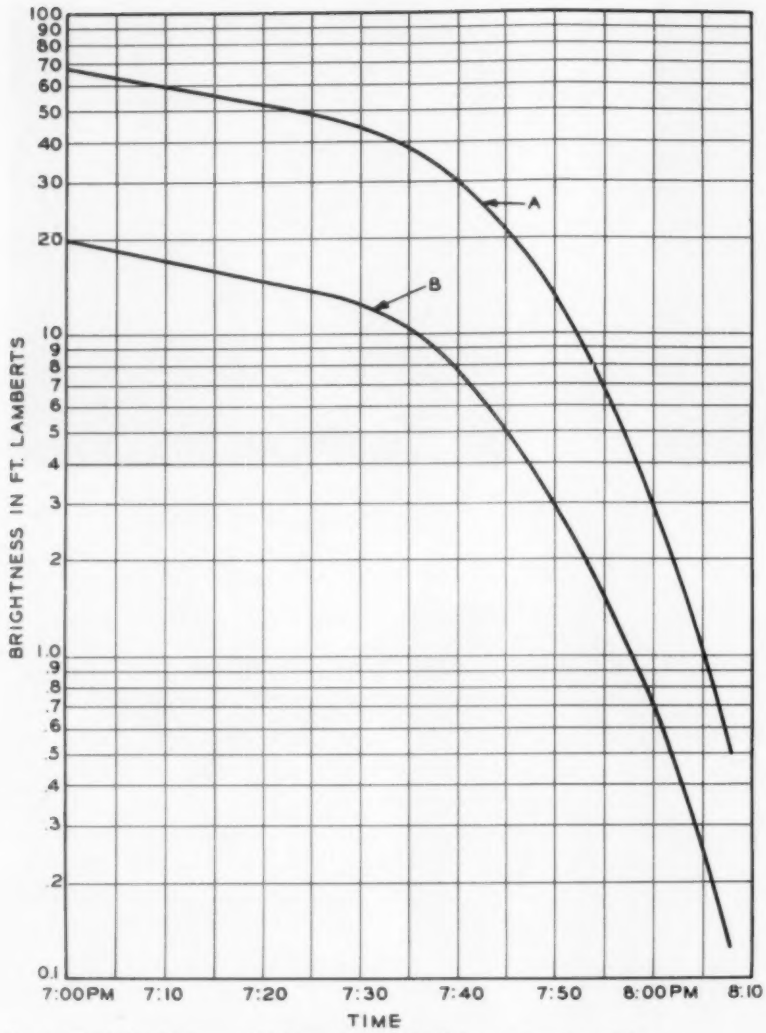


Fig. 17. Variation in screen brightness due to daylight as a function of time.

understand correctly that if you were able to vibrate the screen we have seen here, the improvement would be even greater?

Dr. Beers: No. Unless you were conscious of a screen structure, there would be no improvement. This particular screen material, is perfectly adequate for large-size pictures such as we were reproducing here. The only advantage of oscillating the screen is where you have a very small image and you cannot make the openings in the cellular structure small enough — that is substantially smaller than the finest detail in the picture that you want to see. But as far as the effect on ambient light, the effect is no different whether the screen is stationary or whether it's moving. It's only some of these other effects such as the ability to see all the information in the picture when viewing the scene off angle or some of these moire effects that you encounter due to the dot structure in the tricolor tube.

Mr. Lewin: Could you not get the same effect from a simple rectangular structure?

Dr. Beers: If you are viewing a television image, in which the scanning lines are horizontal, and use a rectangular structure, you will run into interference effects with the scanning lines. If you oscillated a structure with rectangular cells, you would get scanning in only one direction; you would not get the benefit of both the vertical and horizontal scanning components obtained with the honeycomb structure which has no straight lines in any direction.

Mr. Lewin: I meant that with a rectangular structure you would rotate the whole thing 45 degrees so that your lines would be at an angle instead of horizontal.

Dr. Beers: But they're straight lines and they're far more prone to interfere with information in the picture than something of an irregular character. If you use such a structure you might find it necessary to oscillate the screen with a circular motion rather than a simple horizontal motion.

C. R. Skinner (Skinner, Hirsch & Kaye): When you do find it necessary to oscillate the screen, is there any relation between the rate at which you oscillate? Do you have to go more than 16 times a second, for instance?

Dr. Beers: The only requirement is that the rate be sufficiently fast so that the eye is unable to retain a distinct impression of the screen structure. If you were to use a vertical screen motion, since the scanning of television images is in a vertical plane, you might run into some other difficulties and might have to synchronize the motion of the screen with the vertical scanning of the picture, to obtain satisfactory results.

Mr. Skinner: What was the best frequency that you found, or did you determine that?

Dr. Beers: We simply increased the rate to a point where the structure was no longer visible to us and we stopped at 16 cycles a second. The structure, of course, is essentially black and not particularly visible unless you're very close to it.

A Color Schlieren System for High-Speed Photography

By GEORGE E. HAYS

A simple color schlieren system which uses the chromatic aberration of two spherically corrected field lenses to produce a color image has been developed. This system is used extensively in explosion studies and other investigations requiring high-speed photography.

An investigation into the flow characteristics in a ramjet combustion chamber required the use of high-speed photography. The emitted light from the combustion was not adequate to allow successful photography at the required frame speed. A schlieren photograph of the combustion would not be the same as the emitted-light photograph, but it would show the desired gas-flow information.

The subject literature indicated that the simple lenses available could not be used unless the light source was filtered to a narrow spectral band and, also, that elaborate supports would be needed. Some basic experimentation in all phases of the schlieren method was necessary to justify the costs of these operations. The experimentation led to the development of the present schlieren system. Barnes and Bellinger, and Holder[1,2] describe the geometric optics of the schlieren method and Shafer[3] considers the physical-optical problem of the knife-edge obstruction.

The system under discussion (Fig. 1) has three main components: a point source of light; a field-lens system, and a camera-lens system. The point source of light is supplied by a 100-w, zirconium, enclosed arc lamp.[4] This light is collected and made parallel by the first 6-in. diameter field lens, and refocused to a light-source image by the second. The standard 2-in. focal-length Fastax camera lens images the test section, in the parallel light, on the camera film. The camera lens is positioned slightly off axis to allow the lens iris to act as a knife-edge obstruction. The iris cuts off a portion of the light-source image. Any ray that is refracted perpendicular to the knife-edge obstruction, in the total light path, will bend either toward or away from the point of cutoff in the light-source image plane and either reinforces or weakens the test-section image. This change in light density in the final image is representative of the total density gradients existing in the field.

Figure 2 shows the field and objective lenses, the object being photographed and the film plane. Parallel light passing through the test section is focused by the field-lens system to an image of the light source at F. The objective lens focuses the test section on the film. If a knife-edge obstruction is inserted at F, the rays contributing to the film image are intercepted in such a way as to show an overall decrease in film illumination. Insertion at any other point in the light path will cause vignetting of the film image.

Due to the chromatic aberration of the field-lens system, the light-source images of the various colors do not coincide and insertion of the knife-edge obstruction produces uniform darkening for only one color on the film. The effect of insertion of the iris blades at the yellow-light-source image is shown in the color illustrations. Since the red-light-source image is behind the cutoff point, the red rays are intercepted unevenly, thus forming shadings of red in the final image, deep red at the upper portion of the image and less-intense red toward the center. The same effect, in reverse, is true for the blue rays.

A density gradient in the field acts as a small prismatic element with an index of refraction slightly different from that of the surrounding region. This prismatic effect causes a light beam to bend off its normal path. The yellow rays are intercepted evenly, giving a normal schlieren image in this color. The red and blue rays are intercepted unevenly, with corresponding vignetting and a schlieren effect. The bent ray also shifts the point at which it crosses the axis, thus changing its degree of color cutoff, causing a localized change in the image colors. The final image shows a color mixing accompanying the color-band effect. This color mixing indicates the direction of the bent light beam and the magnitude of the schlieren gradient without apparently changing the system sensitivity or resolving ability.

The color mixing may be assigned a quantitative meaning by calculating the required axis shift to produce the observed effect. This calculation is complicated by the considerations of film response and spectral distribution of the light source. These problems have not been sufficiently resolved to refine adequately the analysis to obtain density-gradient data. The main usefulness of the color image has been found to be in the separation of the large schlieren effects from the small by using the color mixing to indicate gross effects and the underlying schlieren image in the background color band as an indication of the small effects.

The system is also useful as a black-

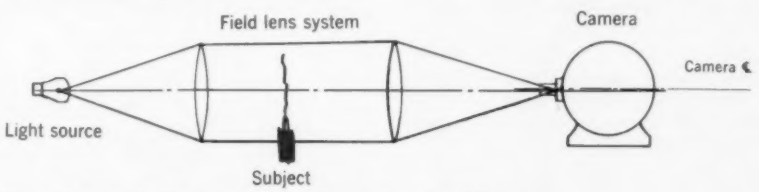


Fig. 1. Schematic diagram of the high-speed color schlieren.

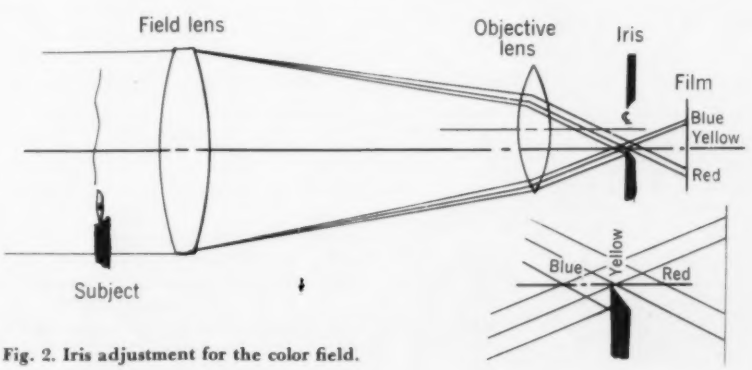


Fig. 2. Iris adjustment for the color field.

Presented on April 21, 1955, at the Society's Convention at Chicago by George E. Hays, Power Plant Research Group, The Boeing Airplane Co., Seattle 14, Wash.
(This paper was received in final form on March 22, 1956.)

Color schlieren photograph of a candle with the camera lens iris inserted from the side. Notice the color mixing.

Typical high-speed schlieren photographs of a turbulent candle flame, taken at 5,000 frames per second.

and-white system. The first successful method of photographing this color image with black-and-white film was to use a film sensitive to only one narrow spectral band, usually the blue, and setting the knife-edge obstruction (lens iris blades) to cutoff at this color. Later it was found that a film, such as Eastman Super XX Negative Film, Types 5232 (35mm) or 7232 (16mm), would be satisfactory if the cutoff plane was on the yellow-light-source image (mid-spectral region). The spectral response of Super XX is fairly constant over the range from blue to red; also, the light distribution from the zirconium-arc lamp does not sharply peak in any spectral region.

The sensitivity of this system may be varied by changing the degree of cutoff at the light-source image. The maximum usable sensitivity shows the density gradient caused by the warm air which rises in the field from a human hand. The use of a circular light source of approximately 0.06 in. in diameter and the method of cutoff that is furnished by the camera-lens iris do not present any problem in adjustment or knowledge of the direction of cutoff. The image, in good adjustment, appears in tri-color, each band clearly defined.

The first step is to adjust the position of the camera until the light-source image at the iris plane is approximately midway between the red and the blue focal planes and centered in the iris for vertical cutoff, or slightly low for a horizontal cutoff. The camera lens is then aimed and focused on the test section and the iris blades adjusted by eye for the proper cutoff. It was found that an excellent schlieren results when these blades about split the light-source image.

The analysis of the color schlieren film is similar to that of other high-speed film; that is, visual examination is followed by the usual time-displacement studies. The color mixing in the image aids in the analysis by outlining the main density gradient without completely obscuring the finer details.

In a lens-type schlieren system, the system aperture is limited by the cost of obtaining good lenses. The problem of obtaining lenses free from striations and well corrected for spherical aberration is reduced by the use of simple lenses.

References

1. N. F. Barnes and S. L. Bellinger, "Equipment for airflow analysis," *J. Opt. Soc. Am.*, Aug. 1954.
2. D. W. Holder, "Color in the wind tunnel," *The Aeroplane*, Jan. 4, 1952.
3. H. J. Shafer, "Physical optic analysis of image quality in schlieren photography," *Jour. SMPE, 52:* 524–544, Nov. 1949.
4. Sylvania Electric Products, Inc., Type C-100.

Some Practical Considerations in the Analysis of High-Speed Motion-Picture Data

By WILLIAM G. HYZER

Fidelity of motion-picture images for both visual and quantitative analysis depends upon several factors including optical resolution, image blur, image contrast, image shape characteristics and differential movement of the image from frame to frame. These various factors were considered in a series of practical tests using standard analytical techniques and equipment to determine the contribution of each factor to the overall accuracy of 16mm film evaluation.

EFFECTIVE analysis of motion utilizing high-speed cinematography requires a knowledge of the limitations of the techniques employed in both photographing the action and in interpreting the resulting image. Two fundamental approaches are commonly employed to analyze high-speed motion-picture films: (1) visual or qualitative analysis of the projected film; and (2) quantitative analysis of the individual frames constituting the action sequence. It was deemed important in our work to determine and compare on a practical basis the interpretive accuracy of each of these two methods. The picture frequency required to record a given action with a rotating-prism camera is commonly determined on the basis of acceptable image blur, usually 0.002 in. for 16mm film. Practical application has demonstrated that this value is not excessive for either the qualitative or quantitative analytical method.

The following equation expresses this relationship:

$$F = \frac{0.4\ DS \cos \phi}{wb} \qquad (1)$$

where F is recommended picture frequency in frames per second; D is shutter-speed proportionality ratio representing the exposure duration in seconds for a picture frequency of 1 frame/sec; S is subject velocity in inches per second; w is field width covered by the lens in inches; b is image blur caused by subject motion in inches; and cos ϕ is the angle between the line of motion and the film plane, in degrees.

There has been some discrepancy in the literature regarding the shutter-speed proportionality ratio for the various makes of rotating-prism cameras. In an attempt to clarify this point, a simple test was set up to compare the effective shutter speeds of the Fastax WF3 and Kodak 16mm high-speed cameras. Two Fastax WF3 cameras were used, one with an old-style prism and the other with the improved, sharp cutoff prism used in currently produced cameras.

A special test film was prepared with a graduated scale running vertically across the frame. This film was placed in the normal film position within the camera. A 45° mirror was placed behind the film so that light from an external source could be projected onto the back of the film. The image of the test film was projected onto a screen located about 2 ft away from the objective lens.

A standard camera lens was used: a 63mm $f/1.9$ lens with the Kodak and a 50mm $f/2$ lens with the Fastax WF3. A graduated scale was clamped within the camera in such a way that the linear movement of the test film could be measured. The accuracy of this measurement was ± 0.003 in. As the film was slowly advanced through the camera, the optical cutoff at any point within the frame area could be observed on the screen. Exact film position was determinable by reading the scale inside the camera.

The shutter-speed proportionality ratio is defined as follows:

$$T = \frac{D}{F} \qquad (2)$$

where T is the time the shutter is open in seconds; F is the picture frequency in frames per second; and D is the proportionality ratio. The published value of D for the Kodak camera is 0.2 (or $\frac{1}{5}$). Various values have been suggested in the literature for the Fastax WF3, ranging from 0.167 to 0.33.

The proportionality ratio, D, was determined experimentally in these tests through the use of the following formula:

$$D = \frac{M}{P} \qquad (3)$$

where M is the film movement through the focal plane of the camera while the shutter is open; and P is the pitch of the film. Both measurements are in the same units, in this case, inches. This determination was made for 16mm film where P has a fixed value of 0.300 in.

The factor M was measured for two image locations within the film frame: (1) at the center of the frame; and (2) at a point midway between the center of the frame and the centerline of the sprocket holes. These positions are designated as "optic axis position" and "quarter-frame position," respectively. The results are given in Table I.

It will be noted in Table I that the shutter speed of the Kodak camera is not $\frac{1}{5}$ of the reciprocal of picture frequency, but more nearly $1/3\frac{1}{2}$. These tests, however, determined the motion-stopping properties of the shutter or the total duration of the shutter open time. From the standpoint of effective exposure of the negative, $\frac{1}{5}$ is a more accurate value.

With the Fastax WF3, shutter speed varies, depending upon image position within the frame. Using the new prism, the shutter is open 70% of the time for an image located on the optic axis and 50% of the time for an image in the quarter-frame position.

Based on these tests, Eq. (1) for estimating required picture frequency, with acceptable image blur as the criterion, is not the same for the Kodak and Fastax WF3 cameras. Approximately twice the picture frequency is required with the Fastax WF3 to achieve equivalency with the Kodak High Speed camera on this basis. Aperture plates of reduced height can be used with the Fastax WF3 camera to increase the effective shutter speed. The aperture plate is located between the film and the prism. Distance between the aperture and film is approximately 0.050 in. Normal size of the aperture is 0.300 in. high by 0.430 in. wide in the WF3 camera. The effect of aperture height upon shutter-speed proportionality ratio, D, for the optic axis position was determined by the same experimental method previously described. Apertures ranging in height from 0.300 in. to 0.003 in. were included in this study. The results are shown in Table II. For a given picture frequency, duration of exposure can be reduced by a factor of 35 times

Table I.

Camera	Shutter-speed proportionality ratio (D)	
	Optic axis position	Quarter-frame position
Fastax WF3 (old prism)	0.90	0.50
Fastax WF3 (new prism)	0.70	0.50
Kodak High Speed Camera	0.29	0.29

Presented on May 2, 1957, at the Society's Convention at Washington, D.C., by William G. Hyzer, William G. Hyzer & Associates, 300 W. Milwaukee St., Janesville, Wis.
(This paper was received on March 27, 1957.)

Table II.

Aperture height, in.	Shutter-speed proportionality ratio (D) at center of frame	Maximum height of exposed frame, in.
0.300	0.70	0.30
0.150	0.56	0.25
0.090	0.36	0.22
0.040	0.19	0.17
0.030	0.15	0.16
0.010	0.06	0.15
0.005	0.03	0.14
0.003	0.02	0.14

by using an aperture 1/100 normal height.

Increased shutter speed is obtained by this method, however, at the sacrifice of exposed frame height. The relation between aperture height and frame height is included in Table I. These data were obtained with the same setup as used for measuring the factor D. Maximum frame height for a given aperture was measured directly from the projected image. A 2-in, $f/2$ lens at maximum opening was used for these aperture-plate studies.

The resolution of the Kodak High Speed camera at the center of the frame using Super XX film processed in X-Ray Developer is 32 lines/mm with the 63mm, $f/2$ lens stopped down to $f/5.6$ and 36 lines/mm with the 25mm $f/1.9$ lens stopped down to $f/5.6$.[1] The resolving power of the Fastax WF3 camera using Du Pont 931 film (reversal processed) and with the 50mm, $f/2$ lens stopped down to $f/5.6$ is 40 lines/mm. These tests are not strictly comparative, so the above information should not be misconstrued as meaning that one make of camera is capable of producing a sharper image than the other. It can be stated, however, that 40 lines/mm represents a fair value for the optimum resolving power obtained with these two makes of rotating-prism cameras.

The effect of image motion on resolving power was reported by Wolfe and Lamberts.[2] This study experimentally demonstrated that the limiting resolving power of a blurred image occurs when the image displacement equals the space between the centers of adjacent bars in a resolving-power chart.

A further result of this study was the following equation:

$$\frac{1}{RP} = \frac{1}{RP_e} + \frac{1}{RP_m} = \frac{1}{RP_e} + 25.4b \qquad (4)$$

where RP is overall resolving power, in lines per millimeter; RP_e is the resolving power of the camera in the absence of image motion; RP_m is the resolving power resulting from image motion and b is the image motion or blur in inches. This equation is useful in predicting the resolving power that can be expected for a given shutter-speed characteristic. The highest resolving power obtainable with a motion-picture camera is determined on the basis of negligible image motion. The lowest resolving power ultimately obtainable for a given image velocity and picture frequency is predictable on the basis of Eqs. (1) and (4) for the limiting case of a shutter speed approaching the reciprocal of picture frequency.

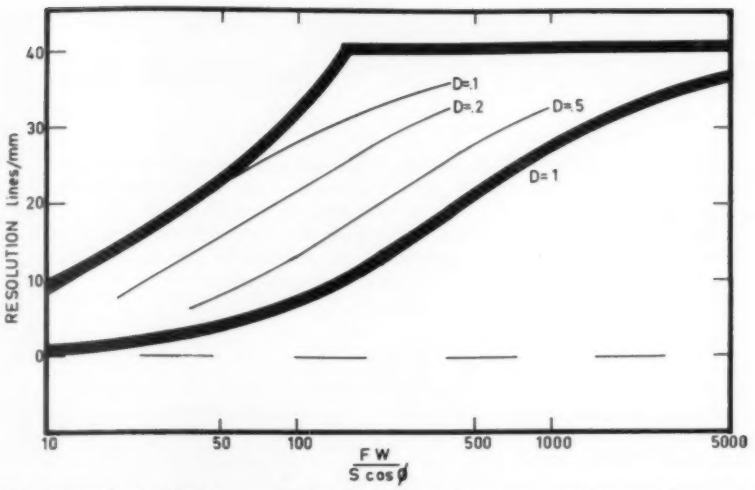


Fig. 1. Envelope of limiting resolution for motion-picture cameras imposed by maximum optical resolving power, minimum shutter-speed characteristic and maximum visual resolving power for moving images.

Based on these findings, the resolving power characteristics of a rotating-prism, high-speed camera lies within the envelope shown in Fig. 1, bounded on the top by the maximum optical resolving power, on the bottom by the limit of resolution imposed by a hypothetical shutter that is open 100% of the time and on the left by the resolution limitations of the human eye. The visual characteristic curve, providing the left-side boundary of the diagram, expresses the approximate resolving power of the eye for projected images moving across the field of vision, obtained by taking stop-motion pictures of a Bureau of Standards Resolving Power Chart as it was moved in incremental distances across the camera's field of view. The chart was mounted on the tool post of a lathe and moved at right angles to the optic axis in increments varying from 0.63% to 5% of the frame width per frame. The resulting films were projected at 16 frames/sec on a beaded screen to an image size of 26 in. Viewing the screen from a distance of 8 ft, observers were asked to select the particular chart that could just be resolved.

Although this criterion of visual resolution of projected motion appears to be somewhat dependent upon projection-image size and viewer distance, the data in the curve represent a typical set of conditions used in analytical practice and are considered sufficiently reliable for the semiquantitative purposes of this paper. The curves shown within the diagram are characteristics of various shutter-speed proportionality ratios. The lefthand boundary curve might be thought of as representing the limiting resolution obtainable for visual analysis using a shutter speed of infinitely short duration. It becomes evident that visual resolution of detail based on the criterion of the parallel-bar, resolving-power chart can be improved for both the Fastax WF3 and the Kodak High Speed cameras by decreasing the shutter-speed proportionality ratio to a value within the range of 0.015 to 0.1. This is the order of magnitude obtained using reduced apertures of 0.003 in. to 0.020 in. in the Fastax WF3 camera.

Image blur also determines the accuracy of quantitative measurement

Fig. 2. Author operating Vanguard M-16 Motion Analyzer.

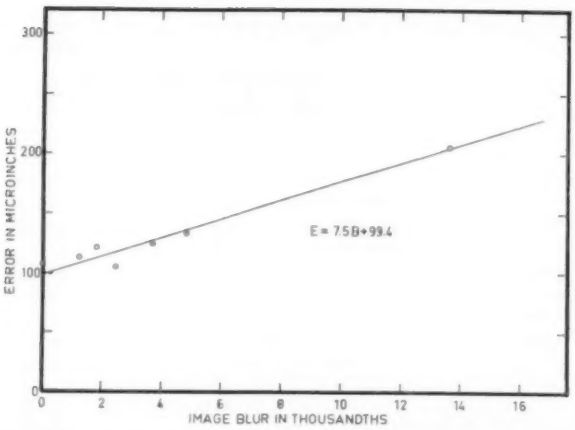


Fig. 3. Plot of image blur vs. measurement error for a high-contrast target.

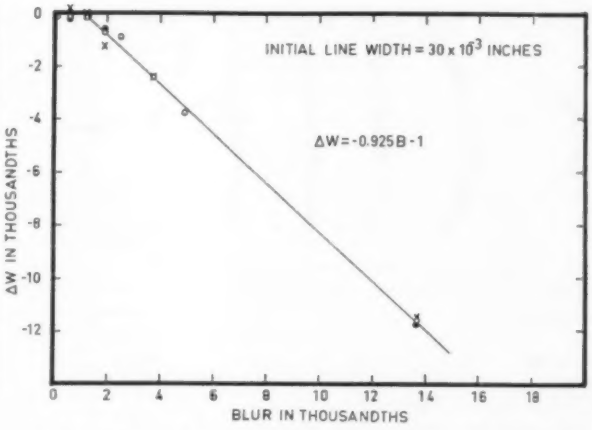


Fig. 4. Relation between image blur and apparent change in line width, Δw, for a high-contrast target.

obtained on an optical comparator such as the Vanguard M-16 Motion Analyzer (Fig. 2). This instrument is an optical measuring device specifically designed for the analysis of motion-picture images. The motion-picture image is projected onto a rear-projection screen, providing a magnification of 10:1. The projection screen is fitted with cross hairs that can be moved by handwheels located at the front of the machine. Cross-hair readings are in inches, tenths and thousandths relative to the projected image, in the common coordinate form, with motion upward and to the right increasing the readings. A reading of 3.528 in. on the micrometer dials corresponds to a reading of 0.3528 in. relative to film dimensions. Measurement error and other image measurements referred to in this paper will be expressed in terms of actual film dimensions. Dials on the instrument can be read to the nearest 0.0005 in. or 50 μin. in terms of film dimensions.

A series of tests was conducted to determine the error of measurement on this device for various degrees of image blur. These tests were conducted using a high contrast (1.4) single-line target mounted on the tool post of a lathe. A Bolex 16mm motion-picture camera was used to photograph the chart as it moved across the field of view. Exposure in this test and in tests to follow were based on incident-light readings. The degree of image blur was varied from 0.000 to 0.014 in. by controlling the exposure time. An experienced operator using the Vanguard M-16 Motion Analyzer made 20 successive measurements of reference-line position using the film obtained on these tests. These measurements were made in a routine manner as would be the case in a typical analysis. Measurement error is expressed in terms of the standard deviation of these measurements. Measurement error and standard deviation are considered synonymous for purposes of this report. Using this criterion, it can be shown that 99.7% of the measurements will not exceed three standard deviations from the mean measurement.

The results of this study are shown in Fig. 3, a plot of measurement error vs. image blur. A straight line was set to the data by the method of least squares. It will be noted from the curve that error for this particular high-contrast target is not what would be considered excessive even for image blurs exceeding 0.01 in. Image resolution in this case is consistent with that obtained in high-speed photographic practice. A high-contrast, resolving-power chart placed in the plane of the target resulted in a reading of 34 lines/mm for an unblurred image. Less measurement error can be obtained with sharper images. For instance, a standard deviation of 60 μin. has been obtained with an exceptionally sharp high-contrast image with a resolution of 45–50 lines/mm using extreme care in aligning the cross hairs with the image.

The effect of image blur upon the measurement of image size is illustrated in Fig. 4. The width of the high-contrast black line used in the above series of tests was measured by several observers using the Vanguard M-16 Analyzer. A plot of change in line width (Δw) vs. image blur is shown in this figure. Apparent shrinkage of the line occurs as the result of image motion during exposure for motions less than the width of the line. This effect contributes to measurement error for blurred images of changing velocity which may exceed the random alignment error of Fig. 3. Error, in defining the exact edge of a blurred line, is $\frac{1}{2}\Delta w$, becoming negligible for image motion less than 0.001 in.

Shape characteristics of image is a significant factor when measurement error is considered. Table III illustrates the effect of image radius of curvature on the mean error of measurement for a high-contrast subject. The target diagram shown in Fig. 5 was mounted on a lathe tool post and moved relative to the Bolex camera for this set of experiments. Mean error was determined by averaging the standard deviations of individual measurements resulting from image motions of 0.0, 0.0006 in., 0.0012 in. and 0.0023 in. These results point to the fact that images of small radius of curvature (less than 0.1 in.) are preferable to straight-edged images. Images of large radius (greater than 0.2 in.) appear to be definitely inferior to both images of short radius and those with straight edges. This can be attributed to the fact that it is difficult for an observer to duplicate the cross-hair alignment at the precise point of tangency with the image when the image is only slightly curved.

In practice, if reference marks are painted or otherwise applied to moving objects to be measured, either a straight line or a curved line of small radius should be used. It is important to keep in mind, however, that the radius of curvature of a circular image should be large in comparison to the blur resulting from image motion. It has been our experience that in cases of excessive blur, straight reference lines are preferable.

The mean measured distances between adjacent lines on the chart shown in Fig. 5 for various degrees of image blur are listed in Table IV. Mean distances in this table are the averages of 10 individual readings. Greatest deviation from the mean in the measurement of distance between two lines for this set of data is 156 μin. These results illustrate the extreme accuracy obtain-

Table III.

Radius of curvature, in.	∞	0.355	0.213	0.093	0.028
Mean measurement error, μin.	115	205	163	103	95

Fig. 5. Test target used to evaluate the effect of image curvature upon measurement accuracy.

able under typical conditions using a high-contrast object target.

The effect of object contrast upon measurement accuracy was studied in the following experiment. Two operators took 20 readings from images of high-contrast (1.4) and low-contrast (0.2) targets. Exposure was the same for both targets, based on the indicated incident meter reading. Image resolution (based on a high-contrast Bureau of Standards Chart) was 30 to 35 lines/mm in both instances. Results are shown in Table V. On the average, about 30% improvement in measurement accuracy was obtained by use of the high-contrast target.

A study of image-measurement error would be incomplete without giving due consideration to optical and mechanical errors contributed by the camera and the analytical measuring device. The magnitude of these combined errors was determined for both Fastax WF3 and the Kodak 16mm High Speed cameras in combination with the Vanguard M-16 Motion Analyzer. A carefully drawn, high-contrast chart, consisting of a series of equally spaced reference lines, was photographed with both cameras on Du Pont 931 film. A 4-in., $f/3.5$ lens was used on the Fastax WF3 camera and a 63mm, $f/1.9$ lens was used on the Kodak High Speed camera. Both lenses were used at maximum aperture. The chart was mounted at a distance of 50 ft from the cameras, care being taken to maintain parallelism between the chart and the film plane. Reference lines on the chart ran in both vertical and horizontal directions from the center of the frame. Variation in separation between adjacent reference lines on the chart was maintained within 0.15%. Maximum error resulting from inaccuracy of the chart would be on the order of 80 μin. or less in terms of image dimensions.

Films were reversal processed and then measured in the Vanguard M-16 Motion Analyzer. Measurements were taken between the center point of the frame and successive reference lines in the diagram for both the vertical and horizontal directions. Results are plotted in Fig. 6. Maximum horizontal distance between the center of the frame and the edge of the picture format is approximately 0.2 in. Maximum vertical distance from the center of the frame is about 0.150 in. Measurements are based on a horizontal image scale factor, 0.14 in. in length, centered on the optic axis. These tests are not intended to compare the relative optical qualities of the two cameras, but, more important, to determine order of magnitude of error introduced by rotating prism cameras under typical operating conditions. The Kodak High Speed camera is at a disadvantage on a comparative basis as a result of using a shorter focal-length lens at a larger relative aperture.

Maximum recorded horizontal error obtained on the test of the Fastax High Speed camera is +0.0001 in. for a distance of 0.114 in. from the frame center. Maximum recorded vertical error was −0.00068 in. for a line located 0.042 in. above the center point of the frame. Greater magnification is obtained with the Fastax WF3 camera in the horizontal direction, which results in vertical error based on a horizontal scale factor. In practice, when the Fastax WF3 camera is used, both a vertical and horizontal scale should be used as a basis for measurements in these two directions.

Maximum recorded horizontal error obtained with the Kodak High Speed camera is −0.0004 in. for a distance of 0.169 in. from the center of the frame. Maximum recorded vertical error is −0.001 in. for a distance of 0.123 in. from the center of the frame. Horizontal and vertical magnification appear to be equivalent at the center of the frame with the Kodak High Speed camera. For optimum accuracy with both cameras, however, it is important that the reference scale be in relatively close proximity to the image distance to be measured. Under this condition, optical distortional error is minimized.

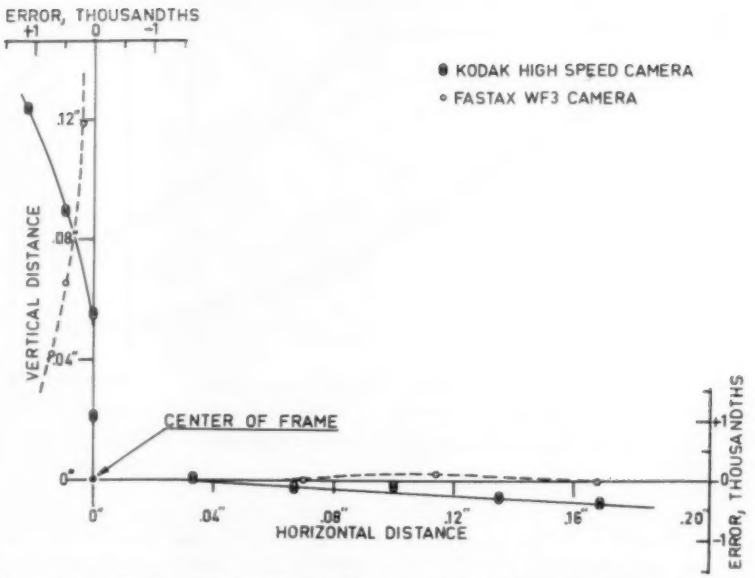


Fig. 6. Distortional errors resulting with two makes of high-speed cameras. All measurements are for distances between the center of the frame and indicated points on the diagram.

Table IV.

Image blur in thousandths	Mean measured distance in thousandths between: Lines A and B	Lines B and C	Lines C and D	Lines D and E
0.00	56.075	45.050	34.360	39.500
0.58	56.145	44.835	34.465	39.630
1.15	56.100	44.740	34.565	39.520
2.30	56.125	44.950	34.500	39.445
Average	56.111	44.894	34.473	39.524
Maximum deviation	0.036	0.156	0.113	0.106

Table V.

	Measurement error, in μin. High-contrast line (1.4)	Low-contrast line (0.2)
Operator "A"	85.8	139.3
Operator "B"	99.0	132.5
Average	92.4	135.9

References

1. Resolving power data reported by D. I. Wood on October 5, 1955, and obtained by private communication with J. H. Niemeyer by the Eastman Kodak Company.
2. Robert N. Wolfe and Robert L. Lamberts, "The effect of image motion on resolving power," *Phot. Eng., 6, No. 4:* 270–274, 1955.

Improved 16mm Projector for Research Films

By S. A. WEINBERG, J. S. WATSON, and G. H. RAMSEY

The flicker-free, slow-motion and single-frame projector described in the November 1954 issue of the SMPTE Journal has been completely redesigned to give more reliable and smoother operation. In the transition from cine to single-frame projection, the 5-blade shutter is shifted to one side, leaving a single 42° blade to occult the film aperture during film transport. An electrical interlock in the push-button-triggering circuit excludes any possibility of overrun and assures uniform registration of successive frames. Also described is an experimental version of the projector with a 10-blade shutter and 12° pulldown. It provides relatively flicker-free projection at speeds from 5 to 3 frames/sec.

In an earlier paper,* the authors described a modified version of the Kodak Analyst projector. The standard Analyst provides film speeds of 16 and 24 frames/sec, its usefulness being enhanced by the ease and rapidity with which the speed can be changed and the direction of film travel reversed. Modification of the film movement, shutter, and drive mechanism made possible the added features of flicker-free projection at speeds as low as 6 frames/sec and pushbutton-controlled, single-frame operation.

Presented on May 2, 1957, at the Society's Convention at Washington, D.C., by S. A. Weinberg (who read the paper), J. S. Watson and G. H. Ramsey, Univ. of Rochester School of Medicine and Dentistry, Strong Memorial Hospital, Rochester 20, N.Y.
(This paper was received on April 17, 1957.)

*S. A. Weinberg, J. S. Watson and G. H. Ramsey, "A 16mm projector for research films," *Jour. SMPTE, 63:* 196–198, Nov. 1954.

Several of these modified projectors were made up for use in our own and other x-ray laboratories engaged in x-ray motion-picture work. In general, the machines performed reliably, but a number of minor faults were noted under working conditions. In order to remedy these faults, and also with a view to commercial production, the 1954 version of the projector was recently redesigned. The new shutter mechanism, illustrated in Fig. 1, retains the five blades of the 1954 version, but is now rimless with one of the blades extending beyond the others. The shutter is mounted at the lower end of a movable arm, **a**, the upper end of which is attached to a ball-bearing sleeve, **b**, allowing the entire shutter assembly to pivot on the main driveshaft, **c**. Pinned to the shaft ahead of the sleeve is a pulley which drives the shutter through a Gilmer timing belt.

Figure 2 shows the shutter assembly positioned on the projector so that only the extended shutter blade can cross the optical axis. This position is the one used in single-frame operation and is maintained by means of a control cam that rides against the nylon block, **b**. Manual clockwise turning of the cam through 20° allows the spring-loaded shutter arm to move to the right for cine operation, bringing all five blades of the shutter into relation with the optical axis and simultaneously starting the drive motor.

In Fig. 3, the control cam, **a**, and a portion of the shutter assembly are shown in cine position. The rod, **b**, that operates the cam, extends toward the rear of the projector and is coupled to a control knob at the back of the projector case (not shown in Fig. 3). After the cam has been rotated into cine position, continued clockwise turning of the control knob gradually increases projection speed from the minimum of 3 frames/sec to the maximum of 18 frames/sec by means of a rheostat on the far side of the mounting plate, **c**.

Turning the knob counterclockwise from full-speed cine position slows the projector down again and eventually acts on the control cam, bringing the shutter assembly back into single-frame position. At this point, a second cam, just visible at **b** in Fig. 4, engages the microswitch, **c**, opening the drive-motor circuit and causing the slowly turning projector to coast to a stop. To move the next frame into place, the motor circuit is closed manually by means of the hand-held pushbutton, the motor starts, and the disconnecting action is repeated. Since only the single, extended shutter blade crosses the optical axis, and that

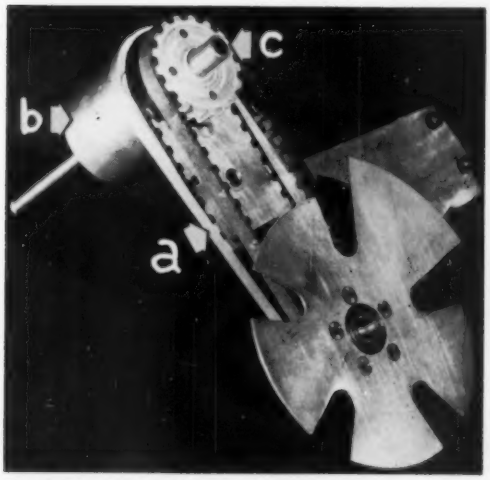


Fig. 1. Five-blade shutter assembly. The shutter proper is mounted at the lower angle of the L-shaped arm, **a**, the upper end of which is attached to the ball-bearing sleeve, **b**, allowing the arm to pivot on the main driveshaft, **c**. Pinned to the shaft is a pulley that drives the shutter through a Gilmer timing belt. Note that one shutter blade extends beyond the others.

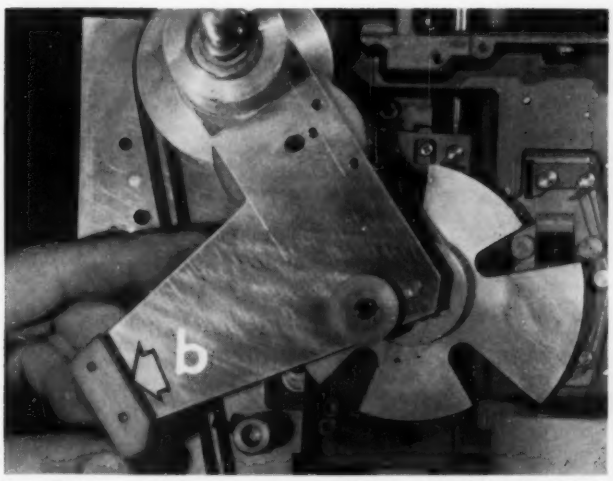


Fig. 2. Shutter assembly mounted on projector and positioned for single-frame operation. It is held in place by a cam acting against the nylon block, **b**. Only the extended shutter blade crosses the film aperture in this position.

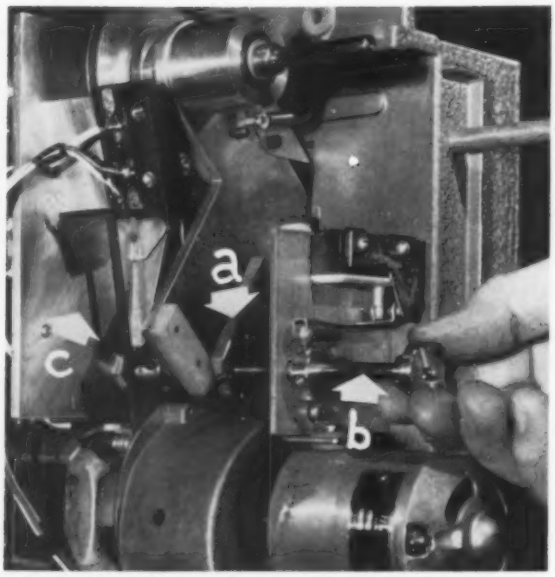


Fig. 3. Left rear view of shutter assembly. The shutter blades are hidden by the lamphouse. Control cam **a** is in cine position. The cam is operated manually from the rear of the projector by means of the rod, **b**, which also controls the motor rheostat on the far side of mounting plate **c**.

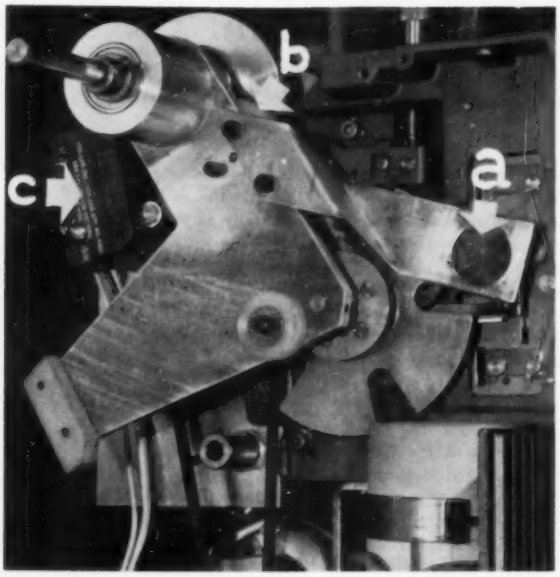


Fig. 4. Shutter assembly from right rear. Lamphouse is removed. Wire-mesh heat filter is at **a**. Drive-motor circuit is opened for single-frame operation by cam **b** which engages microswitch **c**.

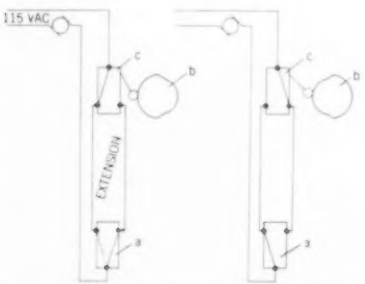


Fig. 5. Diagram of interlocking circuit controlling single-frame projection. Cam **b** rotates 180° for each full revolution of projector driveshaft. In diagram on left, cam engages microswitch, **c**, holding the circuit open. By pressing the pushbutton switch, **d**, the circuit is closed and the projector set in motion. As soon as cam **b** has turned 90° (righthand diagram), microswitch **c** opens circuit causing projector to coast to a stop.

only during film transport, there is no danger of stopping the film with the shutter closed or partly closed, as sometimes occurred with the 1954 version of the projector.

Figure 5 consists of a pair of diagrams illustrating the electrical circuit that controls single-frame projection. The cam-operated microswitch, **c**, already shown in Fig. 4, is of the single-pole, double-throw type, as is also the manually operated pushbutton switch, **d**. The cam, **b** (also partly visible in Fig. 4), is geared down to rotate 180° for each complete revolution of the projector driveshaft. In the diagram on the left, the cam is shown in stopped film position with the circuit between the switches open. By manually activating the switch, **d**, the circuit is closed, as illustrated by the dotted line, and the projector mechanism is set in motion. As soon as the cam, **b**, has turned 90° (righthand diagram) the cam-operated microswitch, **c**, reopens the circuit, causing the projector to coast to a stop in 20° to 30° of rotation of the main driveshaft. Every half revolution of the cam is thus translated into a full revolution of the driveshaft, making a noiseless, electromechanical, single revolution "clutch" that performs reliably whether the motor is running forward or backward.

Shown in Fig. 4 at **a** is the bracket and fine-mesh, heat-absorbing and light-balancing filter. For single-frame projection, the filter moves into position, as shown, between the aperture and condensers. When the shutter is released to

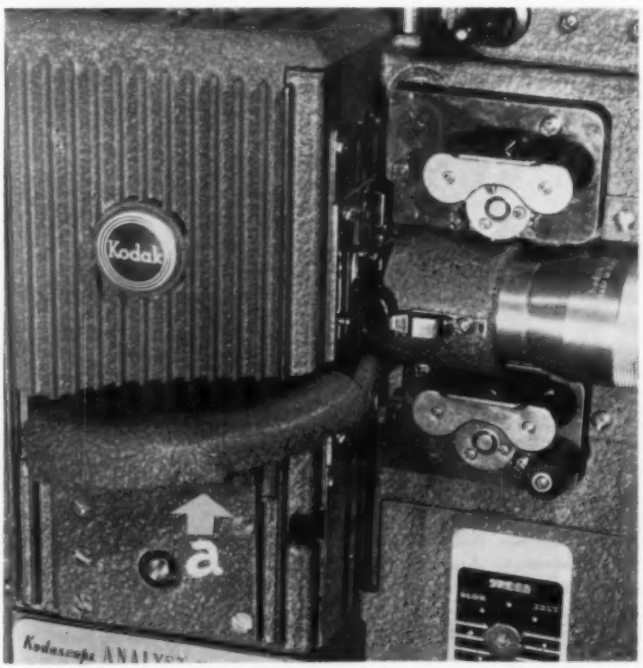


Fig. 6. Right side of projector. Air duct **a** diverts air from blower at base of lamp chimney to front of film gate.

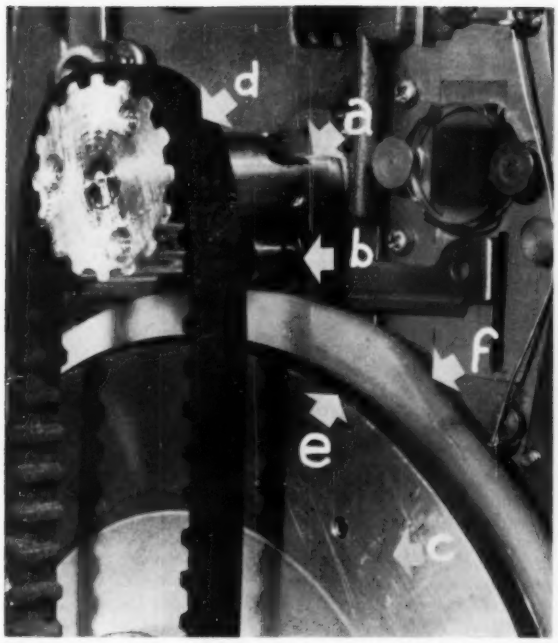


Fig. 7. Experimental 3-frames/sec version of projector. Cam and pulldown mechanism viewed from right rear. Main projector driveshaft is seen at **a**, steel cam follower at **b**, cam hub at **c**, belt linking camshaft with sprocket driveshaft at **d**, belt connecting cam with drive motor at **e**, and 12° ramp on nylon rim of cam at **f**.

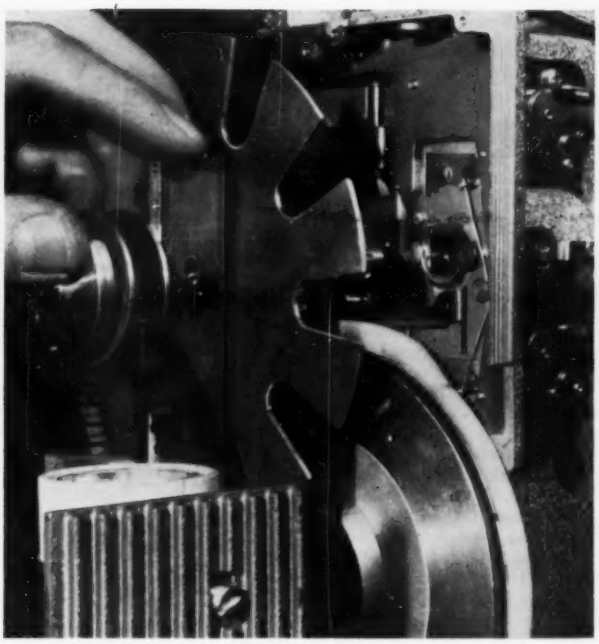


Fig. 8. Experimental 3-frames/sec projector. The 10-blade shutter is seen from the right rear in cine position. The shutter assembly pivots on the camshaft (hidden by lamp socket). The shutter is driven from this shaft by a Gilmer timing belt at left.

the right for cine projection, the filter is positioned out of the way above the aperture. Cooling of the film is aided by the air duct, shown in Fig. 6 at **a** which diverts air from the blower housing at the base of the lamp chimney and directs it against the front of the film aperture. This, together with the wire-mesh heat filter, allows projection of a single frame for an indefinite time without buckling.

Special Slow-Motion Projector With 10-Blade Shutter

In order to minimize flicker at projection speeds between 3 and 5 frames/sec, an experimental version of the modified Analyst was made up with a 10-blade shutter. The new shutter assembly resembles the 5-blade version except that the axis on which it pivots is below the shutter. In the 5-blade version it was possible to steepen the standard Analyst cam to give a 25° pulldown, thus adapting it to the 42° dark sector characteristic of this shutter. However, each dark sector of the 10-blade shutter occupies only 25°, necessitating a pulldown of 12°. Since 25° is about the limit of speedup possible with a cam of conventional dimensions, a new and larger cam was designed for the 10-blade version, as illustrated in Fig. 7, at **c**.

It will be noted in Fig. 7 that the standard cam has been removed from the driveshaft, **a**, and that the standard nylon cam follower has been replaced with a similar member, **b**, made of steel. The pulldown arm is now spring-loaded downward upon the cam's nylon rim. A Gilmer belt, **d**, connects the driveshaft with the shaft carrying the new cam, the latter being belt-driven directly from the motor through a grooved pulley, **e**, alongside the nylon rim. The in-and-out cam is cut in the far face of the nylon rim, the cam follower being provided with a collar that bears against it in conventional fashion. The 12° pulldown ramp is shown at **f**.

Figure 8 is a more inclusive view from the same angle as Fig. 7. The 10-blade shutter assembly is seen in cine position and hides the cog belt, between the driveshaft and camshaft, that was conspicuous in Fig. 7. The 10-blade shutter assembly pivots around the camshaft (here hidden by the lamphouse), and the shutter itself is belt-driven from this same shaft. Film transport time at 3 frames/sec is 0.02 sec. Single-frame operation and speed control are the same as in the projector modification first described. However, due to the abruptness of the cam, the top speed of the unit is limited to about 5 frames/sec, mainly because of unsteadiness at faster speeds.

Except in specific instances, little advantage is offered by projection frequencies of 3 to 5 frames/sec as compared with the greater flexibility of the 6 to 18 frame/sec projector, and it is not planned to produce the slower version commercially.

Discussion

George Lewin (Army Pictorial Center): This has nothing to do with the projector itself, but I'm very curious for more detail, if you would, as to how you made the double exposure?

Mr. Weinberg: The method is basically very simple. This method of making x-ray motion pictures, in a sense, involves nothing more than photographing the x-ray image on a fluorescent screen. Upon removal of the fluorescent screen, the cinefluorographic apparatus functions as a conventional motion-picture camera. The fluorescent screen which has been removed is replaced with a sheet of glass or Lucite, and a smaller fluorescent screen of predetermined size is attached to the transparent surface. In this case the replacement screen was shaped to conform to the shape of the mouth and upper esophagus in lateral position. The model or patient is then positioned on the far side of this screen so that the x-rays will pass through the patient and form an x-ray image on the screen. Inasmuch as this cut-out screen is smaller than the head of the subject, that part of the head and neck not covered by the screen will be recorded in the conventional manner. There is a small amount of geometric enlargement of the x-ray image due to the point source of the x-rays, but this is not very objectionable.

William Youngs (U.S. Information Agency): What size lamp do you use in the projector?

Mr. Weinberg: The projector I have demonstrated to you has a 750-w lamp. A 1000-w lamp may be used, but in single-frame projection there will be slight "buckling" of the film which may require focus correction each time a fresh frame is projected. With the lesser heat of the 750-w lamp, there is seldom need for focus correction. A point I neglected to mention is that the total light output of the projector is about 15% less than that of the unmodified projector. However, more frequently than not, the use of this projector is confined to small laboratories where the slightly lesser screen illumination is not an inconvenience.

news and reports

81st Convention

700 Registrants — 14 Sessions — 103 Papers

One of the most dramatic events in the annals of SMPTE climaxed the 81st Convention when an audience of approximately 200 gave a standing ovation to George Lewin of the Army Pictorial Center following the presentation of his paper on "Transparent Magnetic Tracks." This is the first instance of such a spontaneous demonstration recorded in SMPTE history. Mr. Lewin's paper described his "accidental" discovery of a method of reproducing an optical soundtrack on film which already has a full-width magnetic track. This discovery presages new approaches in the use of languages, sound and film.

The 81st Convention was noteworthy not only for the record number of papers but also for the consistently high quality of the presentations. One consequence of the Convention was the clarification of the significance of certain observable trends, such as that toward a greater interest in closed-circuit television and its applications.

The audio-visual session was attended not only by engineers but by business men and educators. John Flory of Eastman Kodak Co. released some astonishing figures illustrating the economic significance of the increasing use of audio-visual film and equipment.

An unusual session was held at Walter Reed Army Medical Center. The entire session was presented on closed-circuit color television to demonstrate some of the applications in medical training. Many bizarre scenic shots fascinated the audience as the cameras were switched about the Center. The beauties of the epiglottis and the strange scenery of the esophagus were exceeded in interest only by the enormous teeth that appeared on the screen when the scene moved to the dental clinic.

The demonstration brought out how closed-circuit TV can be important in medical training and in the development of new techniques in medicine and surgery. From the beginning of the session, when the Session Chairman, Axel Jensen, appeared on the screen to introduce Dr. Paul Schafer, head of Walter Reed Television Division, the audience of 200 was intent on watching the large screen.

The two Laboratory Practice Sessions were comprised of a final total of 18 papers, making Wednesday a very substantial day indeed.

Another interesting session emphasized the importance of missile photography and its relationship to national defense and to new fields of research.

The Final Program was not greatly different from the Advance Program given in the March *Journal* — in effect, against five papers canceled or not read there were added two papers and a panel discussion.

The fine organization of the large papers program was accomplished by Joseph E. Aiken, assisted by Topic Chairmen Ellis W. D'Arcy, Ralph N. Harmon, John Flory, Garland C. Misener, Fred E. Aufhauser, Herbert Behrens, John H. Waddell, S. M. Lipton, John A. Maurer and Jack C. Greenfield. Substantial contributions to the success of this Convention were also made by Papers Committee Regional Chairmen, under Ben D. Plakun. They are a "standing" committee and are again listed in the May *Journal* as already at work for the 82d Convention.

Many Motion Pictures

An unusual aspect of the Convention was the presentation of a large number of motion pictures for entertainment and instruction, including the delightful "Short Subjects" arranged for by Ethan M. Stifle. Although the Railway Express strike broke up the exact schedule of films, the cartoons, sports and travel shorts were all enthusiastically received throughout the week.

One of the more unusual films was the *History of the Cinema* made by Halas and Batchelor of London and released through Louis de Rochemont Assoc. Ranging from the wildly amusing to the delicately witty, it offered genuine historical instruction from a "different" point of view. This film was selected as the outstanding short for the Royal Film Performance in 1956.

Sound and Story, shown before the Friday afternoon Sound Session, was a thorough presentation by Radio Corp. of America, showing how high-fidelity disk records are made.

Shown throughout the papers program were these films which largely or completely served as a technical paper presentation:

Standardization — A Dynamic Key to Economy, Herbert C. Ruckmick, U.S. Naval Photographic Center, Anacostia, D.C. This 20-min, 35mm film explained the basic concepts and benefits of standards and the standardization process for local or international scope and for government or industry.

Effects of Communication Research on Educational Films, William H. Allen, System Development Div., The Rand Corp., Santa Monica, Calif. When Dr. Allen was obliged to cancel his personal appearance at the Convention, an 18-min film was produced — photography by John Tyo and artwork by James Fitzgerald, both of the Rand Corp. The film, made in half a day and at a cost of $150 drew particular attention as a feature of the Session on Audio-Visual Uses of Motion Pictures and Television. It also enjoyed a further showing in Washington at the U.S. Information Agency

Fall Convention Papers Program

Following the extensive outline in the May *Journal*, one Topic Chairman has been added:

Television Studio Practices, *Richard S. O'Brien*, CBS Television, 485 Madison Ave., New York 22.

Up to the present time, no chairman has been appointed for the topic of Television Film Reproduction Technique, nor have any papers on this subject been received. Anyone who has such a paper to offer should get Author Forms from any of the Regional or Topic Chairmen listed in May, from the Editor at Society Headquarters, or write direct to the 82d Program Chairman:

Dr. Deane R. White
c/o Photo Products Dept.
E. I. du Pont de Nemours & Co.
Parlin, N.J.

The above advice is for anyone who has a prospective paper for the Convention. No one has to wait for an invitation. All prospects are reviewed for suitability for a Convention Program; all prospects are reviewed for suitability for *Journal* publication. Acceptability for a Program is not a guarantee for *Journal* publication, and the reverse is also true.

A Canadian Regional Papers Committee has been formed under the Chairmanship of:

Rodger J. Ross, 784 Duchess Dr., Applewood Acres, Port Credit, Ont., Canada.

Newly appointed members are:

Gerald G. Graham, Box 6100, Montreal 3, Que.

Ivor B. M. Lomas, 275 Billings Ave., Ottawa 1, Ont.

M. J. Pappas, 1778 Beaudet St., St. Laurent, Que.

It is expected that additional appointments will soon be made for Vancouver, B.C., and Winnepeg, Man.

Deadlines

Before August 1, the Program Chairman, Dr. White, must have received from prospective Program authors: the Author Forms; three copies of a 50- to 75-word abstract, typed double-spaced; and two self-addressed business-size envelopes.

Before August 30, copies of the manuscript and brief biographical information, as described on the Author Forms, are due the Program Chairman, the Editor and Publicity Director.

Due to summertime work on the Program, early cooperation will be especially helpful and will ensure proper scheduling of your papers.

HF
REWINDS and ACCESSORIES
REU-1
rewind w/universal joint and end support to hold up to 5 - 35mm reels.
RETWC-1
rewind w/16 - 35mm combination tightwind
REF-1
friction control rewind w/1 reel shaft 35mm.
RE-1
rewind w/1 reel 35mm shaft
SB-1
swivel base attachment for rewind
SP-16 (16mm) spacer
SP-35 (35mm) spacer
IMMEDIATE DELIVERY FROM STOCK... AT BETTER DEALERS EVERYWHERE
ASC-35
35mm aluminum shaft male or female cores
ASC-16 (16mm)
SL-1
spring locks
LS-1
leader stanchion rewind attachments
precision film editing equipment/reels, cans and shipping cases
HOLLYWOOD FILM COMPANY
956 N. Seward Street, Hollywood 38, California HOllywood 2-3284
branch office:
HOLLYWOOD FILM COMPANY
630 Ninth Avenue, New York, New York Circle 6-9309

as an outstanding example of a low-cost film.

New Methods of Recording 16mm Magnetic Lip-Sync Sound Using a Magnetic-Optical Sound Projector, Lee T. Askren and Raymond J. Dwyer, Eastman Kodak Co., Rochester, N.Y. After projecting the film which described the methods and demonstrated results, Mr. Askren answered questions in the usual Convention discussion procedure.

Fader Control for Continuous Printers, Garo W. Ray, Cine Video Productions, Inc., Milford, Conn. After a brief introduction, a film completely described and demonstrated the system. The paper appeared in the April 1957 *Journal*.

New Studio Design Features for Commercial Production, James E. Larsen, Academy Films, Hollywood, was a 7-min, 16mm film which supplemented the paper and lantern slides presented by John Flory for the author.

Table 210, Glenn E. Miller, Lockheed Missile Systems Division, Van Nuys, Calif., was a 35mm color film with narration, showing, step by step, how a documentary film is produced under a military contract. Word-of-mouth publicity for this film caused it to be shown twice during the Convention.

There were, of course, several technical papers with which the authors projected sample film — particularly in the case of George Lewin's paper on "Transparent Magnetic Tracks."

FOR A HAPPY PRESENTATION
The joy of accomplishment is a universal happiness. Especially in the case of a film which is your creation, born out of hard work and careful planning.
Because Precision's staff of specialists adds its own creative efforts to yours by the use of *specially* designed equipment, and by careful handling and intelligent timing – you might say we are fellow creators, working with you to bring out all you've put into the original...Yes, and maybe more!
So, when you turn those 16mm dreams into realities, be sure to call upon Precision for the *accurate, sound and exact* processing your films deserve.
Remember: Precision is the pace-setter in processing of all film. No notching of originals – scene to scene color correction, optical track printing, all are the very best... 35mm service, too!
you'll see
and hear
PRECISION
FILM LABORATORIES, INC.
21 West 46th Street, New York 36, New York
A DIVISION OF J. A. MAURER, INC.
In everything, there is one best . . . in film processing, it's Precision

Local Arrangements

Despite the good work of general and local planners before the Convention, there were sufficient cries for help during the week to keep Convention Vice-President Carl Hunt a very popular man. Hotel facilities for exhibits and Society plans for future exhibits were up for some attention — see the separate story on Exhibits which follows.

Local Arrangements Chairman Keith B. Lewis had the heavy responsibility of pre-convention planning and supervision of all arrangements. Howland Pike, Registration Chairman, assisted by Auditor C. E. McGowan, kept registration operations from becoming even normally confused. On the lighter side of events were the results of fine preparations by: Ladies Committee Chairman Henry M. Fisher; Banquet Chairman Dudley Spruill; Entertainment Chairman Lefferts A. McClelland; and Hospitality Chairman Frank H. McIntosh. The success of their efforts may be summed up in the venerable old expression, "a good time was had by all." On the committee to assist Mr. Fisher were Mrs. Keith Lewis, Mrs. Eric Johnston and Mrs. Nathan Golden.

Public address, recording and projection facilities and services were amply provided by the combined efforts of Jack Greenfield, Wilson Gill, William Youngs, Harry De Furia and Don Atkinson.

Hotel arrangements were handled by Arthur Rescher, and transportation by Frank G. Kear. Administrative Assistants for operation of registration and the convention generally were Nick Galminas and Lawrence Wilkinson. James A. Moses, besides being often a special on-the-spot helper, was Publicity Chairman. To the fortuitous combination of know-how, advice and work contributed by Mr. Moses may be attributed the excellent notices of the Convention in the trade-papers and press.

Other Activities

The 81st Convention was officially opened by the traditional Get-Together Luncheon at which SMPTE President Barton Kreuzer made in informal fashion the report appearing at the front of this issue of the *Journal*. The guest speaker at the luncheon was Jack Woolley, Special Assistant to the Secretary of the Navy. Extracts from Mr. Woolley's speech appear on p. 368 in this *Journal*.

Wednesday night is traditionally "fun night" at Conventions when scientists and engineers relax from the responsibilities of the papers sessions and enjoy good food, good company and good entertainment at a cocktail party, banquet and dance. Music for the cocktail party was supplied by Ruth Palmer, accordianist. The Eddie Pierce Orchestra played for the dance and entertainment was provided by The Hubbels, Gene Archer and the Crosby Sisters, singers, dancers and comedians.

Engineering and administrative committees held 20 formal meetings during the Convention. Reports and results of these meetings will be reflected in the *Journal* pages from time to time.—*R.H.*

it's not magic...

it's a "miracle PRESTO SPLICER"

featuring the worlds only **BUTT-WELD METHOD**

FUSES THE FILM BACK TO ITS ORIGINAL CONDITION

- NO ADDED ADHESIVES
- NO LOST PICTURE
- NO DOUBLE THICKNESS
- NO CEMENT
- NO SCRAPING
- INDISPENSABLE TIME AND MONEY SAVER

DARK ROOM SPLICING A BREEZE

A natural for magnetic track, negative, film strip, color, black and white.

Any type film spliced permanently.

All in 2¾ seconds

Sample splice and brochure upon request

DOMESTIC DEALERS

NEW YORK
Camera Equipment Co.
Camera Mart Inc.
Comprehensive Service Corp.
Florman & Babb
National Theatre Supply
Reeves Equipment Co.
S. O. S. Cinema Supply Corp.

WASHINGTON, D. C.
Fuller & d'Albert Inc.

TEXAS—Austin
Bradshaw & Harman

CALIFORNIA—Hollywood
S. O. S. Cinema Supply Corp.

Los Angeles
Birns & Sawyer
Comprehensive Service Corp.

Redwood City
Mark Larwood Co.

WYOMING—Laramie
The Taxidermist

ILLINOIS—Chicago
Television Equipment Co.

Quincy
Gates Radio Co.

NO. CAROLINA—Charlotte
Carolina Film Service Inc.

PENNSYLVANIA—Philadelphia
Foto Mart Inc.

MASSACHUSETTS—Boston
Smith's Photographic Store

FOREIGN DEALERS

CANADA—Montreal, Quebec
Kirshner's Camera Supplies

Vancouver, B. C.
Viewsound Supplies

HAWAII—Honolulu
The Audio Center, Ltd.
L. Hobron Smith

JAPAN—Tokyo
Electronic & Industrial Enterprises Inc.

FRANCE—Paris
Brockliss-Simplex

SWITZERLAND—Geneva
CinegramSociete Anonyme

GERMANY—Wiesbaden
U.F.A. Handelsgesellschaft M.B.H.

PERU—Lima
Pacific International Distributors

MEXICO, D. F.
Deksa S.A.

CHILE—Santiago
Emelco Chilena

FINLAND—Helsinki
Terton Oy

VENEZUELA—Caracas
Micron C. A.

PRESTOSEAL MFG. CORP.

3727 33rd St., Long Island City 1, N. Y.

From Get-Together Luncheon Speech by Jack Woolley

"I am particularly honored to address representatives of the Society of Motion Picture and Television Engineers. Your Society was born at a time when the motion-picture industry had just begun. It is significant that in its 41 years of existence it has undergone expansion, advancement and revisions in order to meet its obligation to the industry it represents. During this same period of time your membership has produced the engineering and technical know-how and skill in order to keep its standards commensurate with the latest technical advances. As a representative of the United States Navy and Marine Corps, it is, I believe, significant that your organization and mine have much in common. The United States Navy has now been in business 182 years. It started with wooden ships and sails and in the same way that your organization has furthered its technical and productive skills to provide the best possible products so has the United States Navy and Marines undergone transition from sail to the use of coal, from coal to the use of oil and now today the tremendous transition from oil to that of nuclear power. . . .

"It is interesting too that the United States Navy and Marine Corps is one of your industries' biggest and best customers. Would it surprise you if I told you that every night across the world the Navy operates some 1,500 theaters? 1200 of these are ships which have movie projectors aboard while about 300 are actually theaters on our shore bases and stations. Moreover at any one time the Navy has in its possession some 16,000 motion picture prints in its possession. As a taxpayer, you will be interested in learning that 80% of the leasing costs of these films on the shore-based facilities are entirely covered by the regular admission fees. The result is that the American taxpayer pays practically nothing for the motion-picture entertainment of our boys in uniform. . . .

"There is a new trend in the Navy and Marine Corps involving training films. The foremost trend is toward more difficult technical subjects with improved skills demanded to visualize them. The scientific nature of the subject matter of most of our films requires very high production standards. Greater skills are needed on the part of writers, artists and cameramen than ever before. The Navy is also utilizing closed-circuit television in this important area of training.

"The second trend is toward different kinds of training films. That is, those which differ from the conventional training film, film strip or photographic report, such as kinescopes. Only a few films have been originally produced in the Navy employing the kinescope technique. However, some fine kinescopes are being distributed to Navy audiences such as CBS's "Revolution in the Navy," produced by Edward R. Murrow.

"The third noticeable trend is toward decentralizing of film-making. This means an expansion of film-making among many field activities and a recognition of the growth and importance of the small and even the individual film makers.

"This all ties in with the new Navy with its attending research and development, new kinds of films to document and teach new developments, and films made more quickly and by more people than in the past.

"Fortunately we have kept pace with new requirements by means of such industry developments as magnetic recording, single system sound cameras, higher speed film in black-and-white, and the new negative-positive color film with associated processing equipment. . . .

"The point that I wish to establish is the contribution of your industry toward the fighting forces of the United States Navy. Your work is with a media of communication which affects public opinion. The unlimited influence of the Motion Picture Industry, whether it be in a theater, a study group or on television, upon the man in the street represents that characteristic unique in the free world, that of a well-informed man. For it is through being well informed and cognizant of the strifes and perils of the communist world that the American taxpayers are willing to maintain military units in the far corners of this globe to protect our homeland. We know that it is good business to do so. We know that without a well-informed public the armed forces of this nation might be reduced to the danger point which has, in the past, led, in some instances, to open conflict."

For
Film Libraries
SUMMERTIME
is
RECONDITIONING
Time . . .

Summer is with us . . . and your prints are out of circulation for a while. So this is the ideal time to have them restored to good condition through Peerless servicing:

• *inspection and cleaning* • *scratches removed* • *defective splices remade* • *perforations repaired* • *curl or brittleness corrected*

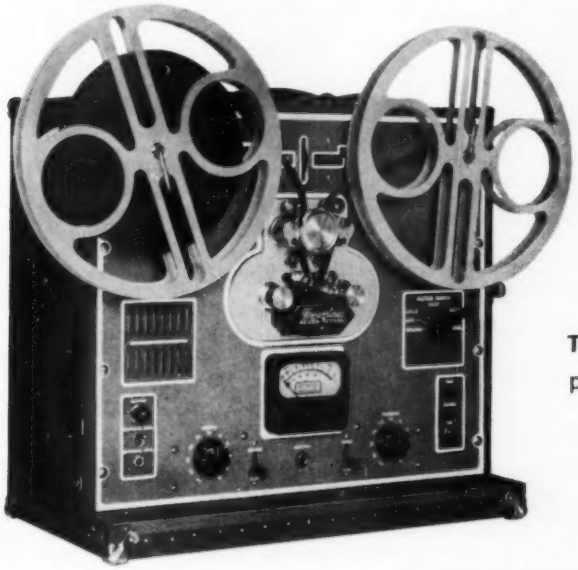
Then, thoroughly rejuvenated, your prints will be ready for hard use in the fall.

Send us your prints *now*

PEERLESS
FILM PROCESSING CORPORATION
165 WEST 46th STREET, NEW YORK 36, N. Y.
959 SEWARD STREET, HOLLYWOOD 38, CALIF.

NEW MAGNASYNC-MAGNAPHONIC ALL-IN-ONE SOUND SYSTEM

cuts set-up time for on-the-go producers



TYPE 15, series 400
price **$1385.00**

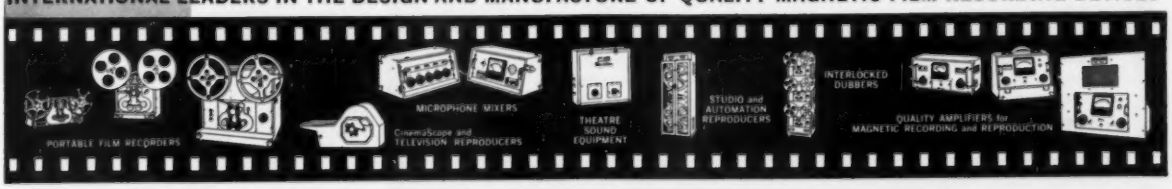
Here, in a single portable case, is a complete, top-quality sound system. Playback monitor amplifier, loudspeaker and recorder are all built into this one compact package. Just open the case and you're in business!

FEATURES—

- Accurate, easy-to-read footage counter.
- Direct coupled torque motors.
- Simplified single-switch for motor control functions.
- Simultaneous film monitor
- "RECORD" indicator lamp.
- 1200-foot film capacity.

Panel size: 19″ x 15¾″; Weight 59 lbs.

INTERNATIONAL LEADERS IN THE DESIGN AND MANUFACTURE OF QUALITY MAGNETIC FILM RECORDING DEVICES



MAGNASYNC MANUFACTURING CO., LTD., 5546 Satsuma Ave., North Hollywood 2, Calif.

MAGNASYNC Magnaphonic SOUND SYSTEM

DEALERS

NEW YORK—Camera Equipment Co., 315 W. 43rd St. New York 36 JUdson 6-1420. Cable Address CINEQUIP.
CHICAGO—Zenith Cinema Service, Inc., 3252 Foster Ave., Chicago 25, Ill. IRving 8-2104.
SAN FRANCISCO—Brooks Camera Co., 45 Kearney St., San Francisco, Calif. EXbrook 2-7348.
INDIA—Kine Engineers, 17 New Queen's Rd., Bombay, India.

Tripod Perfection!

IMPROVED PROFESSIONAL JUNIOR* TRIPOD

ALWAYS A GREAT TRIPOD, the new improved PROFESSIONAL JUNIOR with the removable head, now features the following improvements:

1. Simplified camera attaching method with easily accessible knob—no fumbling under camera platform.
2. Adjustable telescoping pan handle—make it longer or shorter to suit you needs.
3. Additional pan handle sockets for left, right or reverse tilt.
4. Larger gripping area and sturdier construction of tilt and pan locking levers.
5. New tie-down eyelets in flange.

And most surprising, there is NO INCREASE IN PRICE. See, test, try PRO JR.—you'll never want to be without it.

* Reg. U. S. Pat. Off Pat. No. 2318910

SALES • SERVICE • RENTALS

16 & 35 mm Motion Picture Cameras. *PHOTO RESEARCH Color Temperature Meters. *Moviola. *Neumade and Hollywood Film Company cutting room equipment. *Hot Splicers. *DOLLIES — Mole Richardson and Colortran Lighting Equipment.

Complete line of 16mm and 35mm Cameras

ADDITIONAL PRODUCTS—Ace Clear Vision Splicers • Editing Barsels • Editing Racks • Electric Footage Timers • Exposure Meters • Silent & Sound Projectors • Screens • Film Processing Equipment • Film Shipping Cases • Film Editors Gloves • Marking Pencils • Retractable Grease Pencils • Rapidograph Pens • Flomaster Pen Sets • Kum Kleens Labels • Blooping Tape • Blooping Ink • Dulling Spray • Alpha Ray Plutonium Lipstick Brushes • Filters • Used Number & Letter Punches • Camera & Projector Oil.

COMPLETE MOTION PICTURE EQUIPMENT

RENTALS

FROM ONE SOURCE

CAMERAS

MITCHELL
16mm
35mm Standard
35mm Hi-Speed
35mm NC • 35mm BNC

BELL & HOWELL
Standard • Eyemo • Filmo

ARRIFLEX
16mm • 35mm

WALL
35mm single system

ECLAIR CAMERETTE
35mm • 16/35mm Combination

AURICONS
all models single system
Cine Kodak Special
Maurer • Bolex
Blimps • Tripods

DOLLIES
Fearless Panoram
McAlister CRAB
Platform • Western
3 Wheel Portable

LIGHTING

Mole Richardson
Bardwell McAlister
Colortran
Century
Cable
Spider Boxes
Bull Switches
Strong ARC-Trouper
10 Amps 110V AC 5000W-2000W-750W
CECO Cone Lites (shadowless lite)
Gator Clip Lites
Barn Doors
Diffusers
Dimmers
Reflectors

ZOOMAR 35mm

EDITING

Moviolas • Rewinders
Tables • Splicers
Viewers (CECO)

GRIP EQUIPMENT
Parallels • Ladders
2 Steps • Apple Boxes
Scrims • Flags
Gobo Stands
Complete grip equipment

SOUND EQUIPMENT
Magnasync-magnetic film
Reeves Magicorder
Mole Richardson Booms and Perambulators

Portable Mike Booms
Portable Power Supplies to operate camera and recorder

WE SHIP VIA AIR, RAIL OR TRUCK

FRANK C. ZUCKER
CAMERA EQUIPMENT CO., INC.
Dept. JS 315 West 43rd Street,
New York 36, N. Y. JUdson 6-1420

SMPTE Industry Luncheon

An important event that was not, strictly speaking, a part of the 81d Convention activities but which occurred during the Convention was a luncheon which took place May 1 at the Shoreham Hotel, the first of a series of luncheons planned to acquaint leaders in industry and government with the many services offered by the Society.

The guests were selected from among the key personnel in government who deal directly in motion pictures and television.

Officials of the Society and guests heard Axel Jensen, SMPTE Vice-President, describe the SMPTE engineering program and its significance to industry and government. The luncheon was in line with the Society's expanding program of service to science and industry.

Mr. Jensen's presentation was dramatized by charts and visual aids relating the growth of the Society to the growth of industry and illustrating the organization of the Society and its services to members.

Guests at the SMPTE luncheon were: Joseph E. Aiken, Naval Photographic Center, NAS; Charles F. Armstrong, Mgt. Asst., Photographic Division, Bureau of Aeronautics, Navy Dept.; Calle A. Carrello, Chief, Motion Picture Prod., Dept. of Agriculture; Capt. C. H. Clark, Commanding Officer, Naval Photographic Center, NAS; Robert Coar, Chief, Senate Recording Studios, U.S. Senate; George W. Colburn, SMPTE Treasurer; James H. Culver, Head, Motion Picture Div., Library of Congress; James W. Cummings, Assistant to Chief, National Archives & Records Service; George R. Donnelly, Chief, Motion Picture & Photographic Division, Dept. of Commerce, Business & Defense Services Administration; Walter Evans, Asst. Head, Motion Picture Dept., Naval Photographic Center, NAS; Arthur L. Foster, Chief, Motion Picture Lab., Dept. of Agriculture; Dr. John G. Frayne, SMPTE Past-President; James E. Gibson, Chief, Motion Picture Service, Office of Information, Dept. of Agriculture; Jack C. Greenfield, Chief Transmission Engineer, Naval Photographic Center; Wilton R. Holm, SMPTE Secretary; G. Carleton Hunt, SMPTE Convention Vice-President; Axel Jensen, SMPTE Engineering Vice-President; Barton Kreuzer, SMPTE President; Keith B. Lewis, SMPTE Chairman, Washington Section; Col. W. W. Lindsay, Chief, Army Pictorial Service, Pentagon; Glenn E. Matthews, SMPTE Editorial Vice-President; James A. Moses, Chief, Film Distribution, Army Pictorial Service, Pentagon; William A. Mueller, SMPTE Member Public Relations Committee; Comdr. Jesse L. Pennell, Director, Photographic Division, U.S. Navy, Bureau of Aeronautics; Reid H. Ray, SMPTE Member Public Relations Committee; Dr. Paul W. Schaefer, Director, TV, Armed Forces Institute of Pathology, Walter Reed Army Medical Center; John W. Servies, SMPTE Financial Vice-President; Norwood L. Simmons, SMPTE Executive Vice-President; Ethan M. Stifle, SMPTE Section Vice-President; C. S. Stodter, SMPTE Executive Secretary; and Willard Webb, Chief, Stock & Reader Div., Library of Congress.

Exhibits

The equipment exhibit, which grew from the planning first of Walter W. Trimby and then, after his transfer away from Washington, of his successor, Fred W. Gerretson, brought together 22 companies in a total of 27 booths. The following firms were represented:

Andre Debrie Mfg. Corp., New York
Animation Equipment Corp., New Rochelle, N.Y.
Camera Equipment Co., New York
Filmline Corp., Milford, Conn.
Oscar Fisher Co., Peekskill, N.Y.
Florman & Babb, New York
Jack Frost Elec. Co., Detroit, Mich.
The Harwald Co., Evanston, Ill.
Hollywood Film Co., Hollywood
Houston Fearless, Los Angeles
Kling Photo Corp., New York
Neumade Products Corp., New York
Precision Laboratories, Brooklyn, N.Y.
Prestoseal Mfg. Corp., Long Island City, N.Y.
PSC Applied Research, Ltd., Toronto, Ont., Canada
Radio Corp. of America, Camden, N.J.
Roll-O-Matic, Temple, Pa.
S.O.S. Cinema Supply Corp., New York
Sylvania Electric Products, Inc., New York
Unicorn Engineering, Hollywood
United Film Corp., Ottawa, Ont., Canada
Zoomar Inc., Glen Cove, L.I., N.Y.

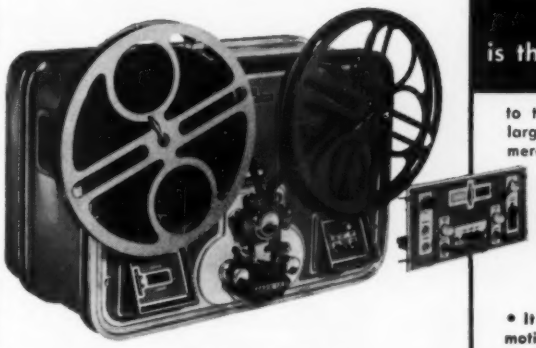
After a somewhat slow start, due in part to the fact that registration during the first two days was fairly light, activity picked up nicely and exhibitors were kept happily busy with visitors and inquiries. There were many items of particular interest, among them two from abroad having their first viewing in this country — the PSC Applied Research processor from Canada, and the Union Tonfilmbau printer from Germany — but the greatest notoriety that attached to any exhibit was certainly that which grew up around the Houston Fearless rapid processor, by virtue of the fact that it was not there. This little $50,000 item, the size of a small room, had been shipped from the West Coast and thence apparently into limbo. As day after day passed by and the haggard faces of the Houston Fearless representatives grew longer and longer, reports of the equipment's whereabouts varied by the hour, and it was not until the day before the Convention closed that a truck appeared with the processor which bore indications of having spent some time in Miami.

Perhaps the most important event of the week as far as exhibits are concerned was a meeting that was held by the exhibitors and some of the Society's officers to discuss the future development of the Society's equipment exhibits. Over the past two or three years experience in organizing and conducting these has been collecting piecemeal; now the exhibits have grown to a point where constructive planning is called for to ensure that they serve the best interests of the industry at large and that they occupy a proper position in relation to all the other components of an SMPTE convention.

As an outcome of this meeting, it was resolved that a permanent committee of exhibitors from the industry should be con-

CAMERA EQUIPMENT COMPANY

presents the new Magnasync Magnaphonic Sound Recorders



For quality & economy MAGNASYNC is the perfect answer—

to the needs of film producers, large or small, feature or commercial, because—

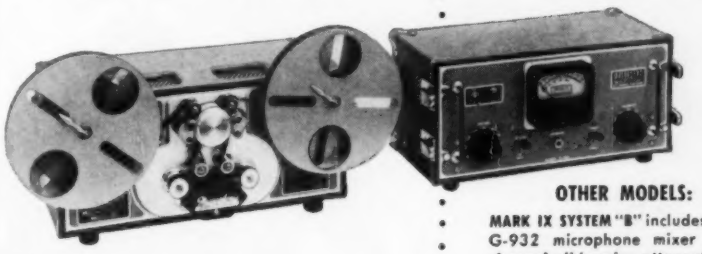
- It delivers clean, distortion-free sound.
- It is compact, lightweight, portable, meets the latest SMPTE standards.
- It serves every segment of motion picture and spot TV production.
- Purchaser is not required to pay royalties on footage consumed.

BUT MOST OF ALL, the MAGNASYNC MAGNAPHONIC line contains exclusive features found in no other recorders, yet all carry low, low price tags.

Trust your own ears—trust your Sound Man's judgment. Switch to MAGNAPHONIC SOUND.

The New MARK IX
MAGNAPHONIC SOUND SYSTEM, SYSTEM "A"

with built-in record play amplifier and remote control assembly is an engineering achievement with exclusive features found in no other recorder. Has recording, playback, and bias oscillator circuits enclosed in separate plug-in assemblies; easy accessibility to all amplifier components; push-button motor controls; remote control footage counter, record-play & film-direct monitor switches. Available in 16mm, 17½mm & 35mm priced from $2,145.00



Model X-400

is a completely synchronous 16mm Magnetic film recording channel, professional in every detail. Can be operated in "console" position, as shown, or stacked as one unit. Features simple camera or projector interlock, instantaneous "film-direct" monitoring, and low power consumption. Ideal for the low budget producer.

$985.00

OTHER MODELS:

MARK IX SYSTEM "B" includes Model G-932 microphone mixer with 2 channel slide wire attenuators.
$2,820.00

MARK IX SYSTEM "C" includes Model G-924 microphone mixer and remote control assembly packaged in matching portable case.
$2,520.00

TYPE 5 features built-in Monitor amplifier, separate overdrive torque motor, record gain control, and playback control. Priced from
$1,570.00

Prices subject to change without notice

FRANK C. ZUCKER
CAMERA EQUIPMENT CO., INC.
Dept. JS 315 West 43rd St.,
New York 36, N. Y. JUdson 6-1420

The Society's new permanent display. First shown at the International Photographic Exposition in Washington in March, it was photographed at the Society's Spring Convention at the Shoreham Hotel. It will be used at SMPTE conventions and other appropriate technical exhibits to illustrate the various services offered to the industry by the SMPTE.

stituted to work with the Society's officials in helping to establish general policy with regard to future exhibits and to cooperate in the planning for each exhibit as it comes along. The members of this committee are:

Oscar Fisher, Oscar Fisher Co., Peekskill, N.Y.
Arthur Florman, Florman & Babb, New York
Paul Klingenstein, Kling Photo Corp., New York
Harry Teitelbaum, Hollywood Film Co., Hollywood
James L. Wassell, Bell & Howell Co., Chicago

The first action to be undertaken by this committee will be the preparation of a questionnaire, to go out jointly from the Committee and the SMPTE to all former exhibitors at SMPTE conventions, calling for expressions of opinion on such basic policy matters as frequency of exhibits, preferred locations and opening times.

It is intended that this shall be a continuing and mutually helpful cooperation between the industry and the Society which will help to put the exhibits in proper perspective and give due emphasis to the important part they play in promoting the interest and success of the conventions. Great care is given to the planning of the technical sessions that form the meat of the program; equal attention must be paid to providing adequate and suitably located space for the equipment exhibits, to planning the convention schedule so that sufficient time is available for viewing them, and to providing, wherever possible, a link in subject matter between the equipment shown and the technical papers presented that will enhance the value of both.—*D.C.*

SMPTE Engineering Committee Manual

This booklet, which was first prepared a couple of years ago in order to present a clear picture of the committee structure by which the Society's engineering activities are carried on, has now been revised to bring it up to date.

Although it is primarily intended as a guide for committee members and especially for new appointees, members of the Society in general will find this a most convenient reference for this important part of the Society's functions. It describes the way in which the engineering committees and subcommittees are set up, the role that committee members and chairmen play, how the exchange of information is carried on by meetings and published reports in the *Journal*, and the Staff Engineer's position as co-ordinator and helper to all the committees under the administrative supervision of the Engineering Vice-President.

A particularly useful feature is the clear step-by-step account of how engineering proposals in our field are processed with the eventual aim of publication as American Standards. This is illustrated by a block diagram.

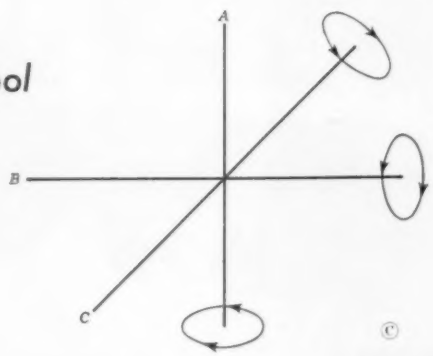
Copies of the Manual may be obtained by members, free of charge, from Society headquarters.

SMPTE Lapel Pins. Gold and blue enamel reproductions of the Society symbol, with screw back. Available to all members from Society headquarters. Price $4.00 including Federal Tax; in New York City, add 3% sales tax.

This is the symbol

of the

ORBITAL



MAGNETIC HEAD MOUNT

All adjustments rotate about the mid gap axis point without altering magnetic head recording media contact pressure. Applicable to magnetic sound recorders, magnetic sound cameras, magnetic sound printers, computers and magnetic data storage of all types. This mount, with head, is of special appeal where space is limited, and can be installed within drum or sprocket diameters from 0.765 in. Your inquiries are solicited

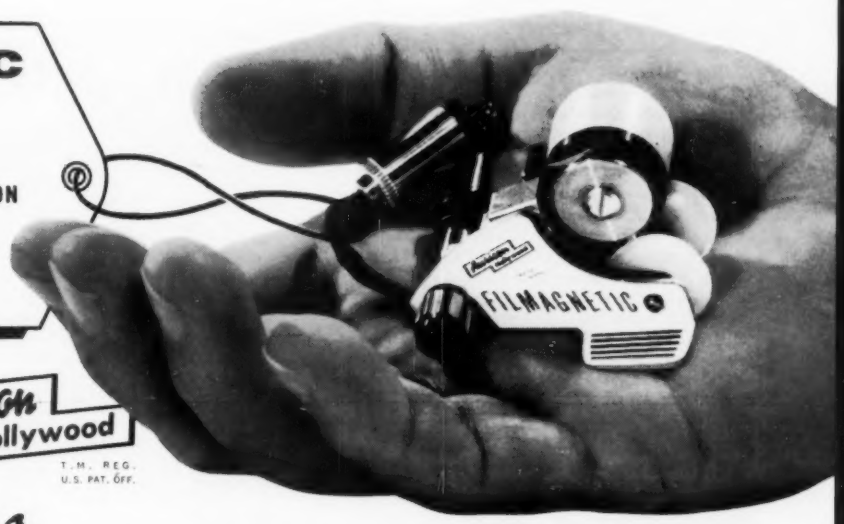
A development of

D'Arcy Magnetic Products, Inc.

Box 1103, Ogden Dunes, Gary, Ind. Tel: Twin Oaks 5-4201

FILMAGNETIC
TRADE MARK

AN *Optional* FEATURE
AVAILABLE FOR FACTORY INSTALLATION
ON ALL NEW OR EXISTING AURICON
OPTICAL SOUND-ON-FILM CAMERAS



Auricon Hollywood
T. M. REG. U.S. PAT. OFF.

Presenting AURICON
FILMAGNETIC
TRADE MARK

Auricon proudly presents "Filmagnetic" High-Fidelity sound-on-film Recording, for lip-synchronized Talking Pictures and Music of Quality, on 16 mm black and white or color film pre-striped for magnetic sound before it is exposed to light. "Filmagnetic" sound and optical picture are recorded Single-System on the same film at the same time! The "Filmagnetic" Unit, installed at the Factory in any Auricon Camera, can be temporarily removed without the use of tools, thus providing a choice of High-Fidelity Optical or Magnetic sound-tracks. Your pre-striped film with magnetic sound lip-synchronized to your picture, passes through the normal picture-development and is played back on any 16 mm Magnetic Sound Projector, including the Ampro, B&H, RCA, and others.

"Filmagnetic" Outfit complete . . . $870.00

PLEASE MAIL COUPON BELOW FOR FREE INFORMATION . . .

"FILMAGNETIC" SOUND FOR COLOR OR BLACK & WHITE

(FILMAGNETIC PATENTS PENDING)

"Filmagnetic" Twin-Head Camera Recording Unit, with Record and Instant-Monitor Magnetic Heads, which automatically open for easy threading . . . complete with Model MA-10 Amplifier, $870.00 installed on any new Auricon Camera at the Factory. Small extra installation charge on existing Auricon Cameras.

"Filmagnetic" 3 Input Amplifier, Model MA-10, with High-Fidelity Microphone, complete Cables and Batteries, in a Cowhide-Leather Carrying Case. Super-portable, weighs only 7 pounds, carries easily with shoulder-strap during operation!

GUARANTEE
All Auricon Equipment is sold with a 30 day money-back guarantee. You must be satisfied!

Distributed by Graybar
OFFICES IN PRINCIPAL CITIES

Auricon Hollywood — 16 MM SOUND-ON-FILM SINCE 1931

AURICON Division
BERNDT-BACH, INC.
6946 Romaine Street
Hollywood 38, California

☐ Please send me free information on "Filmagnetic" equipment for Auricon Cameras.

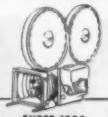
☐ Without obligation, please send me cost of installing "Filmagnetic" on my Auricon Model.....Camera.

NAME.....TITLE.....
FIRM.....
STREET.....
CITY.....ZONE.....STATE.....

THE Auricon Hollywood LINE

CINE-VOICE $795.00

AURICON PRO-600 $1497.00


SUPER 1200 $4652.15

Education, Industry News

Nearly a quarter-million students are in accredited engineering colleges, the highest number since, and almost equal to, the all-time high of 1947, when World War II veterans were in school, according to figures compiled by the U.S. Office of Education and the American Society for Engineering Education. Electrical engineering is the most popular specialty, although up to this year, mechanical engineering led the field. Civil, chemical, industrial and aeronautical engineering follow.

At the same time that the ASEE announced these and many other statistics regarding the engineering college population, it announced that in cooperation with the Midwest College Placement Association it has prepared a new "code of ethics" on Recruiting Practices and Procedures. The code says, in effect, that industry, colleges and students must especially seek to be prompt, businesslike and honest in their placement activities because of the temptations of today's keen demands for graduates.

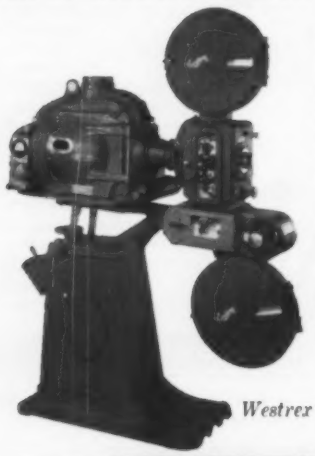
Employers should avoid "elaborate entertainment and overselling." There should be no "special payments, gifts, bonuses or other inducements," nor should there be reward for a third party who may prevail upon a student to accept an employment offer.

On their side, students "should not hoard or collect job offers." The student should advise other prospective employers when he accepts an offer from one, and should not accept other interviews. He should not accept invitations to plants or headquarters unless "sincerely interested" in the employment prospects there, and he should present expense accounts for such trips only for directly incurred expenses.

The colleges can contribute by encouraging businesslike interviews, discouraging "indiscriminate shopping," advising but not "unduly influencing," and by giving interviewers complete information about graduating students.

"Recruiting Policies and Procedures" may be obtained for 25¢ per copy from the American Society for Engineering Education, University of Illinois, Urbana, Ill. Discounts are given on quantity purchases.

Small theatre audiences like GOOD SOUND, too!



Westrex offers newly designed, economical, high-quality sound systems to small theatre owners. The trouble-free Westrex *Economy* Sound Systems use small, compact Reproducers, 30-watt Power Amplifiers, and two-way Loudspeaker Assemblies.

Westrex is synonymous with sound quality in theatres all over the world. Your theatre, regardless of size, can have an extra dimension of sound, *with savings*, if you buy from Westrex.

Westrex Economy Photographic Reproducer

Westrex Corporation

111 Eighth Avenue, New York 11, N. Y.
Hollywood Division 6601 Romaine Street, Hollywood 38, Calif

STUDIO RECORDING SYSTEMS
•
THEATRE SOUND SYSTEMS

Public schools in eight cities are participating in a national program for the promotion of teaching by television. The Fund for Advancement of Education has alloted $986,000 to finance the program. Schools in Atlanta, Cincinnati, Detroit, Miami, Norfolk, Oklahoma City, Philadelphia and Wichita and in two States, Nebraska and Oklahoma, have received grants, which are matched dollar for dollar by the schools. Regular classroom instruction is scheduled to begin when schools open in September. In announcing the program Dr. Alvin C. Eurich, Vice-President and Director of the Fund, mentioned the success of TV educational programs in Hagerstown, Md., St. Louis, Pittsburgh and Chicago.

Another experimental program in a low-income section of New York City is making a new approach to adult education. Approximately 600 families who live in a public housing project in the Chelsea district of Manhattan will be able to view closed-circuit educational programs in their own homes. The neighborhood chosen for the experiment includes many residents who speak only Spanish and who have difficulty adjusting to city life.

The project, which has received a grant of $200,000 from the Ford Foundation for Adult Education, is co-sponsored by the Hudson Guild Neighborhood House, by the Board of Education and by Language Research Institute, a nonprofit foundation with headquarters at Harvard University.

The project will employ three origination points with switching units. Programs will originate at Hudson Guild, Public School 33, and the Lower West Side Health Center and will stress good citizenship, health programs and language instruction.

Telemovies (Cable Theaters) have been brought one step nearer actuality with the signing of a contract between Video Independent Theatres, Inc., and Southwestern Bell Telephone Co. Under the terms of the contract, Video will construct the coaxial cable for the Bartlesville, Okla., telemovie theater at the expense of the Telephone Company from whom Video will then rent the cable and utility poles. Video Independent Theatres is installing its own tap-out lines from the cable to subscribers' homes.

Exhibitors generally seem to be adopting a "watchful waiting" policy toward cable

MARATHON NEWSREEL

CAPTURES ACADEMY AWARD FOR BEST ONE-REEL SHORT SUBJECT FOR 1956

USING ARRIFLEX 35 MM CAMERA

Ever photograph an object skimming along at more than 250 miles an hour? This was the tough assignment given to Marathon TV Newsreel and the results were so spectacular that Marathon achieved the ultimate for organizational teamwork—they won an Oscar.

The short subject entitled "Crashing the Water Barrier," was directed by Konstantin Kalser, Executive Producer, and filmed with an Arriflex 35 at Lake Mead, Nevada. Cameramen were Henry V. Javorsky and Harry W. Walsh working in co-operation with Ken Baldwin, supervising editor and other members of the Marathon Newsreel team. Reuven Frank was the writer.

Marathon cameramen are agreed when they say, "We rely on the Arriflex 35's dependability and versatility in everyday production and in getting those once-in-a-lifetime-shots."

"Crashing The Water Barrier" the 1956 Academy Award winner was released by Warner Brothers and photographed with an Arriflex 35, using Eastman 35 color negative.

Sold only through franchised ARRIFLEX dealers

SOLE U. S. DISTRIBUTOR

KLING

PHOTO CORPORATION

257 FOURTH AVENUE
NEW YORK 10, N. Y.

7303 MELROSE AVENUE
HOLLYWOOD, CALIF.

Representatives in the following cities: BOSTON • CHARLOTTE, N. C. • CHICAGO • DENVER • DETROIT • HOUSTON • KANSAS CITY, MO. • HOLLYWOOD, CAL. • MEMPHIS • MIAMI • NEWARK • NEW YORK • PHILADELPHIA • SAN FRANCISCO • SEATTLE

Arriflex 35 Camera
Model IIA, $1735.00
Lenses & Magazines Extra

The Arriflex 35 belongs to the Kling family of fine West German photographic products.

FOR *Your* EVERY NEED

THE EASY TO USE

SENSATIONAL NEW
Movie-Mite
Supreme

Custom features at mass produced price

SAVE 1/3

☐

SMPTE MEMBERS
Here's a quality projector designed for professional use with rugged, precision construction. Guaranteed a lifetime. Easiest to use. Easiest to carry. Only 27½ lbs.

Complete **$298.50**

☐ SPLICE-O-FILM

The finest hot automatic splicer in the world. Fastest, strongest professional splices. Only $99.50

☐ Harwald STORAGE CABINETS

for Beauty
Safety
Convenience
Efficiency
Economy.

☐ Moviscop VIEWER

The very finest 16mm action viewer. Precision German mechanism. For producers—T.V.—Labs.

Please check squares above for complete information on any or all items shown and mail this ad to:

THE HARWALD CO.
1216 Chicago Ave., Evanston, Ill.
Phone: Davis 8-7070 SJ

theater. Ernest G. Stellings, President of Theatre Owners of America, regards the new development as "economically unsound." Mitchell Wolfson, President of Wometco Theatres of Florida, has said that cable theater might be practicable in countries where the government regulates industry but not under the American system of free enterprise.

The National Audio-Visual Convention and Exhibit to be held in Chicago, July 20–23, will stress the theme of public relations for the audio-visual field. The program will include such topics as Basic Public Relations Ideas and How to Work With Press, Radio and Television. A slide set produced for the Audio-Visual Commission on Public Information by Adrian TerLouw of Eastman Kodak Co. will be shown for the first time.

Rodney D. Chipp has been appointed Manager of Systems Engineering, Radio Communication Laboratory, Federal Telecommunication Laboratories, Nutley, N.J. He was formerly Director of Engineering for Allen B. Du Mont Laboratories, Inc. During the time he was with that organization he took an active part in the reconstruction of an 80-year-old building which is now the Du Mont Telecentre (*Jour. SMPTE*, pp. 535–42, Oct. 1956). In his new position Mr. Chipp will be in charge of advanced planning which will require liaison with both military and commercial communication agencies. In addition, he will coordinate the systems engineering of the various radio communication projects.

Emerson Yorke has announced the organization of a new company, Laguna Productions, Inc., 433 So. Beverly Dr., Beverly Hills, Calif., for the manufacture, purchase and sale of motion-picture and television productions. Mr. Yorke's associate in the new venture is Edward W. Ballentine who will be in charge of sales, distribution and exploitation. Both men are members of the Society. Mr. Yorke is an independent producer and Mr. Ballentine is, at present, with Acme Film Labs, Los Angeles. The first feature production to be released by the new company will be *The Cardinal's Secret*.

John E. Holmes has been appointed Sales Manager of Roger Wade Productions, Inc., 15 W. 46 St., New York 36. A member of the Society, Holmes was with NBC for 15 years in recording, radio and television. Prior to his present appointment he was Vice-President in Charge of Sales of the Automatic Projection Corp. and District Sales Manager of Viewlex, Inc.

Formation of Selling Films, Inc., a subsidiary of Roger Wade Productions, Inc., 15 W. 46 St., New York, has been announced. The new company will specialize in films and audio-visual aids for "outside" salesmen. Robert L. Shoemaker will be in charge of the new activity as Executive Vice-President. The special type of films is described as providing "automation for the outside salesman."

Obituaries

John A. Norling, 61, died May 24, 1957, at his home at 31 Whistler Road, Yonkers, N.Y. He was born August 6, 1895, in Bizerte, Tunis, Africa.

A graduate of the University of Minnesota, he served from September 1917 to February 1919 in the Photographic Division of the U.S. Army Signal Corps. At the conclusion of his army service he became associated with Bray Productions, Inc., New York, where he developed new methods of making animated drawings for motion pictures.

In 1925 he helped found the firm of Loucks & Norling Studios, 245 W. 55 St., New York. He joined the Society in 1924 and became a Fellow in 1945. At the time of his death, Mr. Norling was Chairman of the SMPTE Committee on Stereoscopic Motion Pictures and was serving on the Standards Committee, the Board of Editors and the Fellow Award Committee.

A pioneer in stereoscopy, he produced the first full-size Polaroid three-dimensional picture for exhibition in the Chrysler Motors Exhibit at the New York Worlds Fair, May 4, 1939. This motion picture was in black-and-white, but a similar subject which he also produced was exhibited in Technicolor the next year.

As a recognized authority on stereoscopy, he was the author of many technical articles which appeared in the *Journal* and other publications. Among his articles which appeared in the *Journal* are "Three-Dimensional Pictures" (Dec. 1939) and "Progress in Three-Dimensional Pictures" (Nov. 1941). In these articles he describes the making of the three-dimensional pictures shown at the Worlds Fair.

His first published article for the Society appeared in the *Transactions*, Sept. 1927, on "Animated Technical Drawings." During the years other articles appeared on various phases of the stereoscopic art. His last article in the *Journal* appeared in March 1953, a reprint from *PSA Journal*, "The Stereoscopic Art." This article contained the comment, "The art of stereoscopy . . . seems to have escaped the concentrated attention of most of the people in the Hollywood area. The men in the drivers' seats of the movie industry have, for the most part, failed to have a vital personal interest in and understanding of 3-D movies."

In the photo Mr. Norling is shown with the 3-D camera he invented. It has a novel

optical system on the front to permit effective variable spacing of twin lenses and accommodates two film strips, while handling like a conventional camera.—*R.H.*

Russell O. Drew

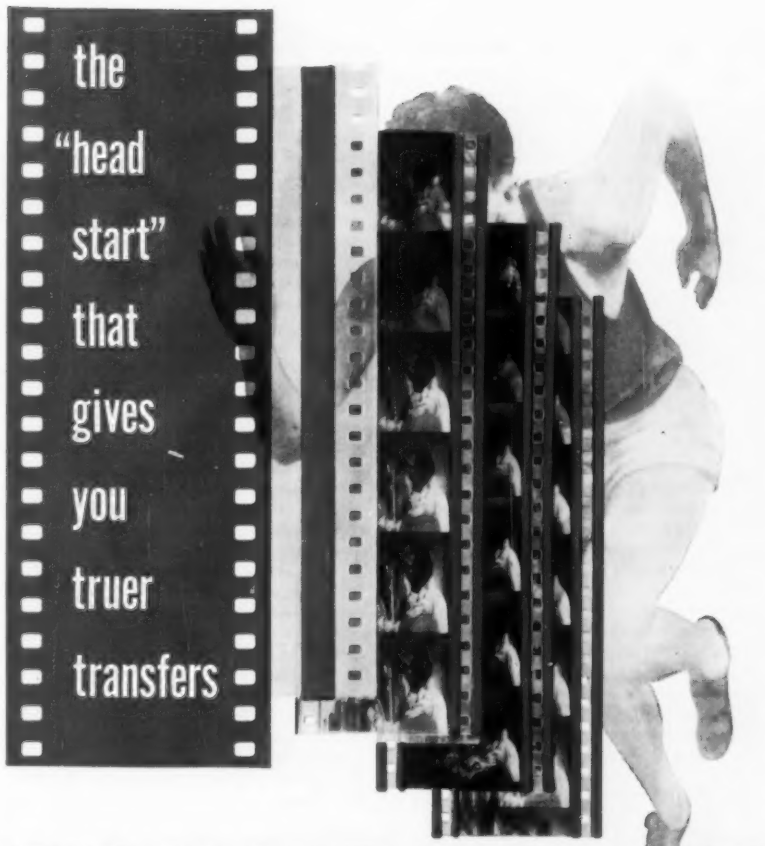
I thank the Editor for the opportunity to pay a tribute to a loyal friend whose genial presence we can now enjoy only in memory. Russell O. Drew died on April 23, 1957. He joined this Society as an Associate in 1937, and in 1953 was made Fellow. He will be particularly remembered by the members of the various committees on which he served. He was RCA's expert and specialist on photographic problems.

Russell Drew was born August 19, 1909 in Smyrna Mills, Maine. Twelve years later his family moved to Portland, Maine, where he attended public school. He took a two-year course in electrical engineering at Wentworth Institute in Boston, where he was class president, president of the student council and valedictorian. He continued his electrical engineering training at Carnegie Institute of Technology, finishing in 1932. He entered the employ of Radio Corporation of America in Camden in 1933, serving in Quality Control until 1937 when he transferred to the Advanced Development group and began working on the photographic problems related to sound for motion pictures. He participated in much of the experimental work on which the contributions of RCA to improved sound were based. Much attention was being given to improvements in 16mm sound, a line of development that assumed great importance to the Armed Services.

In 1941 RCA moved the entire Sound Engineering Department to Indianapolis, and Drew was appointed supervising engineer of the new film laboratory, in which position he continued to serve after the return to Camden in 1946. During the war he was the RCA representative on several ASA committees on war standards. The film laboratory, under Drew's direction prepared large numbers of picture and sound test films, wanted by the Armed Services, and after the war continued to supply test films to this Society.

He was joint author of several technical papers published in our *Journal*, and had served on the engineering committees on standards, color and television. In the television field, Drew with his associates developed improved photography of televised pictures, using ultraviolet light.

Russell Drew was married to Eleanor Flack on November 26, 1936. He was a man of many warm friendships, a vigorous advocate of what he believed in, with wide interests and a gift of humor that was a delight to those who knew him.—*Edward W. Kellogg.*

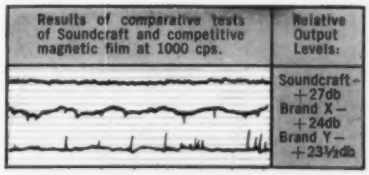


SOUNDCRAFT

FULL-COAT MAGNETIC FILM

The truer your initial recording... the truer will be your final release. Only Soundcraft Full-Coat Magnetic Film, with its greater output, and higher signal-to-noise-ratio... can give you the fullest fidelity **original** sound track!

"Oscar"-winning Soundcraft oxide formulation plus the original Soundcraft Unilevel® Coating and Micro-polishing® processes—result in the exceptional frequency response and defect-free recording surface of Soundcraft Magnetic Film —to give you transfers—**free of drop-outs, noise, distortion and fuzziness.**


Results of comparative tests of Soundcraft and competitive magnetic film at 1000 cps.
Relative Output Levels:
Soundcraft – +27db
Brand X – +24db
Brand Y – +23½db

COMPARE THE UNIFORMITY AND OUTPUT DIFFERENCE!

These Soundcraft Full-Coat and Magna-Stripe Films will speed your sound production, improve your sound quality – and save you money.

FOR ORIGINAL RECORDING | Soundcraft Full-Coat Magnetic Film

35mm – 1000 and 2000 ft. lengths • 17.5mm – 1000 and 2000 ft. lengths
16mm (single or double perforated) – 400, 800 and 1200 ft. lengths

FOR EDITING AND RELEASES | Soundcraft Magna-Stripe and Magna-Stripe Raw Stock

WRITE FOR SOUNDCRAFT MAGNETIC FILM BROCHURE

DO YOU USE RECORDING BLANKS? ... YOUR BEST **SOURCE** IS SOUNDCRAFT!

REEVES SOUNDCRAFT CORP. 10 East 52nd St., N. Y. 22, N. Y. W. Coast: 338 N. LaBrea, L. A. 36, Calif.

Closed-Circuit TV Communications Progress

By NATHAN L. HALPERN

(Condensed from the paper presented on April 30, 1957, at the Society's Convention at Washington, D.C., by Nathan L. Halpern, TNT Tele-Sessions, Inc., 575 Madison Ave., New York 22.)

Closed-circuit television has grown into a major use of television and this specialized television may one day exceed—in the importance of its impact—the far-reaching public effects of broadcast television itself.

It is particularly fitting that this closed-circuit TV progress report be made to the Society of Motion Picture and Television Engineers, because engineers first conceived of closed-circuit uses and because it is engineers by the thousands who sustain its remarkable growth. Of the various types of closed-circuit—industrial, educational, communications, and pay-as-you-see—I intend to report only on closed-circuit TV as a communications system.

Closed-circuit TV communications span space, gobble up geography, and link people and organizations everywhere at the same time. In the past few years sessions by closed-circuit TV have become a primary communications system for business and industry.

A business meeting is televised to specially invited audiences in selected cities throughout the country, gathered to participate in the session as if they were in attendance in person. The receiving locations for business meetings may be hotel ballrooms, auditoriums, theaters, TV studios, company offices, or similar meeting places. In some instances standard television receiving sets are modified to receive closed-circuit signals, but usually large-screen projection equipment (similar in size to motion-picture screens) is utilized for viewing facilities in the closed-circuit hookups. The programs are individually designed to communicate business messages via television to the special audiences.

A few industry statistics will show the tremendous growth of the closed-circuit communications medium. In the last three years more than 100 organizations have spent some $15,000,000 on closed-circuit communications, and at least 4,000,000 persons have been part of the specially invited closed-circuit audiences. Programs have been transmitted into 200 cities in the United States and Canada. There have been exhibitions in more than 400 hotels, as well as 300 theaters and auditoriums.

From 1950 through 1955, there was an average of 50 or so tele-sessions per year. In the past year there were more than 300 closed-circuit tele-sessions, of which the largest dollar volume was in big-screen TV.

The results of the tele-sessions have been so outstandingly successful that corporations have repeated and increased their uses. Among the more frequent users are General Electric, General Motors, International Business Machines, American Telephone & Telegraph, Ford and Chrysler. It is this more frequent use of tele-sessions that indicates the growing acceptance of closed-circuit TV as a regular communications medium.

Call for Code of Ethics

While aggressive selling can be beneficial in building a bigger medium, it becomes dangerous when an unreasonable amount of promotion causes one of the largest corporations to drop its current interest in utilizing closed-circuit television. It is strongly recommended that all of us in closed-circuit television review our standards of good business conduct for our own welfare. It may be that we are approaching a period when it is both necessary and desirable for us to establish general industry standards of business ethics, so that the closed-circuit industry will not be adversely affected by malpractices.

Technical Facilities Stabilized

Two primary factors in closed-circuit television growth are *facilities* and *programming*.

A great deal of care has gone into the development of good technical facilities. Once a bottleneck to development of big-screen tele-sessions, the facilities problem no longer looms large. The leading manufacturers of big-screen TV projectors have provided basically good black-and-white equipment. The Bell Telephone System and other telephone companies have continued to improve the quality and sureness of their transmissions. The telephone companies have set records of millions of miles of closed-circuit television signal transmission. Still, there remains a necessity to allow for sufficient lines to carry closed-circuits at appropriate meeting hours, and a problem of uncertain special construction charges.

The field engineering and technical forces have acquired considerable experience in rendering themselves more skillful and efficient in picture and sound exhibition at each location. A single service company in this field recently announced that its engineers had already achieved a record of more than 50,000 hours in big-screen closed-circuit television.

Although there is room for continuous self-improvement in projection equipment, telephone transmission and field technical services, these facilities have been organized basically in a sound manner.

Our records show that in the past 2½ years, *TNT Tele-Sessions*' big-screen facilities have been 99.7% sure—with a total video loss of less than $\frac{3}{10}$ of 1%. And the quality performance is consistently good in the networks employing standard brand projection equipment, experienced engineers and technicians and careful advance preparations.

There has been an increasing need, however, for closed-circuit companies to develop production supervisors and technicians who can carry over from telecast to telecast the know-how and experience gained in closed-circuit productions. In this way, proper supervision can be given to camera crews and technicians in originating properly for the best possible technical, big-screen quality.

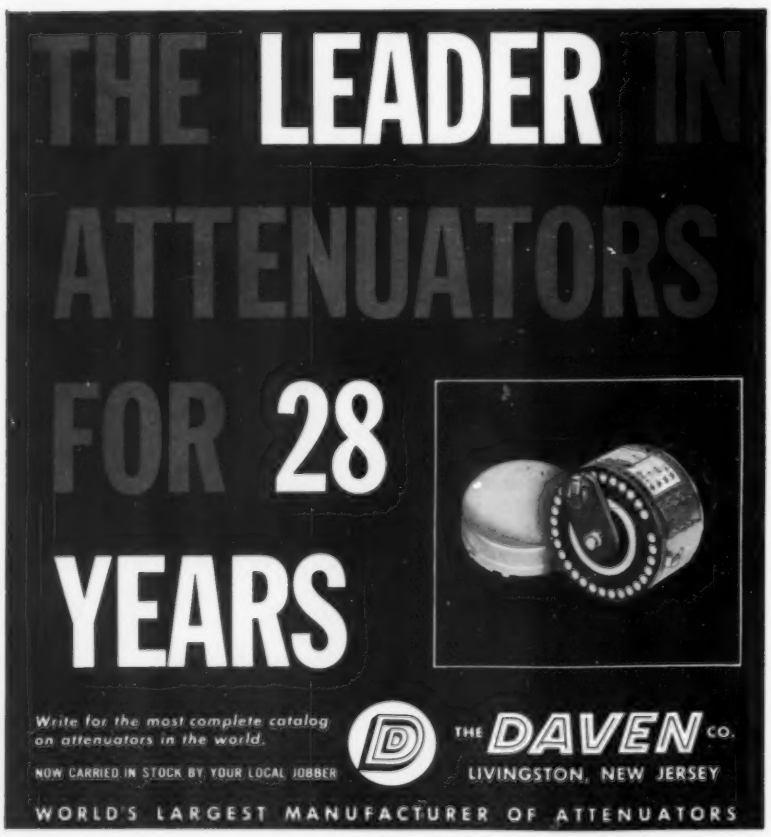
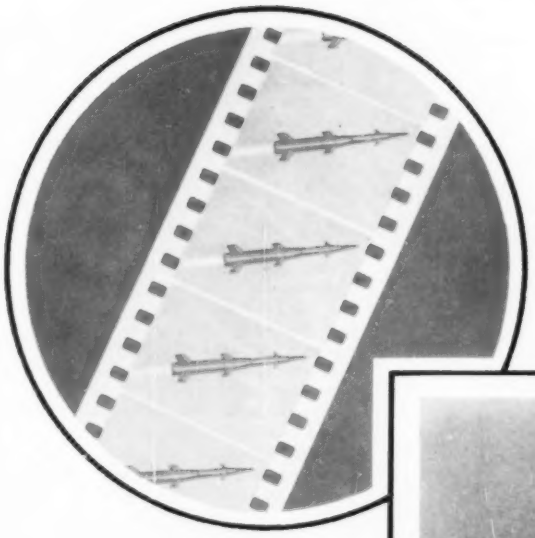

THE LEADER IN ATTENUATORS FOR 28 YEARS
Write for the most complete catalog on attenuators in the world.
NOW CARRIED IN STOCK BY YOUR LOCAL JOBBER
THE DAVEN CO.
LIVINGSTON, NEW JERSEY
WORLD'S LARGEST MANUFACTURER OF ATTENUATORS

PHOTO-SONICS, INC.

MODEL 35m/m – 4B

35m/m HIGH SPEED CAMERA

2800 frames per second

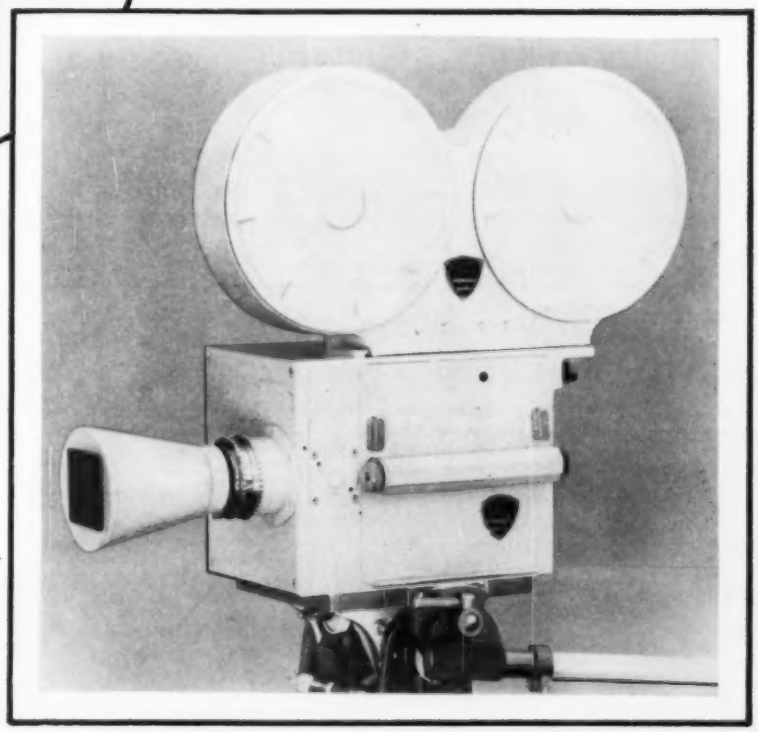


Full 35m/m frame size.

Rotary prism for image compensation.

Interchangeable shutters with 5 to 60° openings.

500 ft. film capacity.



Drive motor – series or synchronous.

Fiducial markers.

Two light timer.

10X viewing tube.

Buckle and runout shut-off switches.

Optional frame rates below 2800.

Lenses available.. 80, 135, 250 & 550m/m.

write for complete Photo-Sonics catalog.

PHOTO-SONICS, INC.

2704 WEST OLIVE AVE. BURBANK, CALIF.

The Role of SMPTE

It is in the field of technical facilities that the Society of Motion Picture and Television Engineers can and should play a more important role in closed-circuit television. It is my earnest hope that at this convention a permanent Closed-Circuit Television Committee will be formed to aid and assist the proper technical growth of closed-circuit TV.

It is to be hoped that the Society will consider guidance to all members of the industry in the proper development of color for big-screen, closed-circuit television. True big-screen color represents the next great technical and business advance in the closed-circuit medium. There are still differences within the industry on the standards appropriate for big-screen color—its proper origination and transmission, as well as exhibition.

In black-and-white as well as color, it would be helpful to receive standards from an industry-wide professional engineering group to develop the best technical practices for proper maintenance of quality in closed-circuit communications.

Programming

The second primary factor responsible for TV development that deserves major attention is *programming*.

Like any medium, it is the content communicated by it which is most important. Thus, it's the show itself that counts. Granted that closed-circuit TV is a dramatic, live medium with enormous impact upon viewers, we have learned that not all shows help establish the validity of the medium itself or serve the best interests of the sponsor

It has been established that closed-circuit television cannot be programmed as broadcasting. Similarly, the approaches of industrial film, live touring shows, and many other methods of communication are inappropriate for closed-circuit TV. This live medium requires an entirely different and unique approach in order to achieve maximum impact.

Recognizing the great need for programming in this business, *TNT Tele-Sessions, an affiliate of Theatre Network Television, Inc.*, created the first full-time Program Department in closed-circuit television, with a leading creative television producer-director at the head.

In effect, the challenge of closed-circuit programming is to create hour-long "commercials" of interest to, and impact upon, the special company audiences. The starting point is always the nature of the audience and the business message to be communicated.

We have learned that the primary purpose of closed-circuit programming is not merely to entertain. The entertainment portion must be carefully integrated so that it communicates properly the message the client wants to convey, thereby instructing and entertaining at the same time.

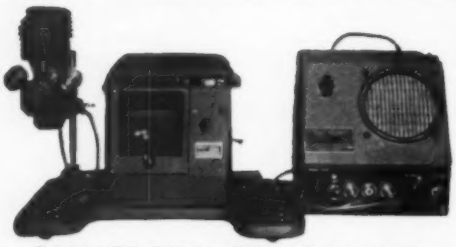
Programs have been built on the idea of two-way video or audio participation from locations all over the network. This has inspired enthusiastic feelings of local group participation in the nationwide meetings.

Earlier stylized presentations of personality close-ups, used without relief in a telecast, have been modified by greater visualizations through use of charts, graphs, film clips and still photographs. Nevertheless, it is interesting to note that, while there have been TV spectaculars in this field—with original book and lyrics, choreography, dancers, stars, etc.—there have been more shirt sleeve business sessions, with closed-circuit programming keyed to making these programs interesting, informative and memorable.

Split screens, supers, matting and other TV techniques have also been adapted to closed-circuit TV programming. Remote pick-ups from company factories, research laboratories and conference rooms, are as commonplace as studio originations. On a single tele-session, we have supervised 32 cameras in 11 different regional originations across the country, with intricate, split-second inter-city switches numbering 27 in 38 minutes. Also, closed-circuit has contributed to the TV record book—by covering a 2½-mile course of the General Motors Technical Center at Warren, Mich., via a mobile TV truck following a Firebird car of the future, beaming the TV signal while on the move, without interruption, to 62 cities throughout the United States and Canada.

All in all, closed-circuit tele-sessions are the modern way for business groups to communicate. And what was a late starter in the television field is now making rapid progress to become first in television importance to our business and industrial way of life.

You Can Depend on CAMERA MART
FOR THE BEST IN MOTION PICTURE EQUIPMENT



CAMART DUAL SOUND READER

- Edit single and double system 16mm or 35mm optical sound.
- Edit single system Magnastripe or double system magnetic sound.
- Easy to attach to any 16mm motion picture viewer to obtain perfect lip-sync matching of picture to track.
- Works from left to right and right to left.
- Magnetic Model **$185.00.** Optical Model **$195.00**

CAMART BABY DOLLY

A fourwheel dolly will provide balance and stability. Portable, has seat for cameraman; will carry assistant & equipment. Dolly tracks available **$425.00**

ECCO 1500 SPEEDROLL APPLICATOR AND CLEANING FLUID

ANTISTATIC *ANTITOXIC*

Cleans, conditions and lubricates your film in one easy operation. Noninflammable, eliminates waxing, absolutely safe. Ecco #1500 Applicator **$29.50.** Ecco #1500 Cleaning Fluid **$9.60** per gallon. Ecco #2000 Negative Cleaning Fluid **$6.50** per gallon.

On the West Coast Camart Products are available from: Birns & Sawyer, Inc., Los Angeles

the CAMERA MART inc.
1845 BROADWAY (at 60th St.) NEW YORK 23 · Plaza 7-6977 · Cable Cameramart

NOW in the East it's . . .

MOVIELAB

for

COLOR

- 16mm - 35mm EASTMAN COLOR Negative - Positive Processing
- Staffed by experienced COLOR technicians.
- Also KODACHROME and ANSCO COLOR Printing.

MOVIELAB COLOR CORPORATION

MOVIELAB BUILDING, 619 W. 54th ST., NEW YORK 19, N. Y., JUDSON 6-0360

SPECTRA

Brightness Spot Meter

- Checks uniformity of blue backing for matte shots directly from camera position
- Checks brightness of selected areas on set to determine brightness range
- Checks color temperature of light sources to maintain uniform color quality
- Shows footcandle output of individual light units without interference from other sources
- Measures uniformity of illumination and discoloration of projection screens for any distance or angle
- Maintains standard brightness and COLOR TEMPERATURE of printer lights

PHOTO RESEARCH CORP.

KARL FREUND, President
837 North Cahuenga Blvd.
Hollywood, 38, Calif.

Professional Services

BERTIL I. CARLSON
Photoproducts Co.
Consultants, designers, builders in PHOTO INSTRUMENTATION
Color Processors • Cameras • Projectors
Box 60, Fort Lee, N. J.
N.Y.Tel. TWining 9-4823

REVERSAL FILM CHEMICALS
for FILM and TV LABORATORIES
ATKINSON LABORATORY
7070 Santa Monica Blvd.
Hollywood 38, California

COLORTRAN CONVERTER
LIGHTING EQUIPMENT
The most illumination for the least investment
CROSS COUNTRY RENTAL SYSTEM
ELIMINATES COSTLY SHIPPING
write for catalog
NATURAL LIGHTING CORP.
612 W. Elk, Glendale 4, Calif.

MITCHELL CAMERAS
16mm—35mm—70mm and accessories
for all applications
Studios—Industry—Science—Research
CHARLES AUSTIN
Technical Representative
521 Fifth Ave., New York 17, N. Y. OX 7-0227

PHOTOGRAPHIC
INSTRUMENTATION
Specializing in
HIGH-SPEED
Motion-Picture Photography
Photographic Analysis Company
100 Rock Hill Rd., Clifton, N. J.
Phone: Prescott 8-6436

CRITERION
FILM LABORATORIES, INC.
Complete laboratory facilities for 16 & 35mm black-and-white and color
33 West 60th St., New York 23, N. Y.
Phone: COlumbus 5-2180

PROFESSIONAL MOTION PICTURE
PRODUCTION EQUIPMENT
Cameras, Sound Recording, Editing,
Laboratory and Affiliated Equip.
Consulting Services by Qualified Engineers
Domestic and Foreign
REEVES EQUIPMENT CORP.
10 E. 52nd St., NYC
Cable: REEVESQUIP

ELLIS W. D'ARCY & ASSOCIATES
Consulting and Development Engineers
Xenon-Arc Applications
Motion-Picture Projection
Magnetic Recording and Reproduction
Box 1103, Ogden Dunes, Gary, Ind.
Phone: Ogden Dunes 2451

WILLIAM B. SNOW
Consulting Engineer
Acoustics—Electronics
Stereophonic Recording
1011 Georgina Avenue
Santa Monica, California
EXbrook 4-8345

FISCHER PHOTOGRAPHIC
LABORATORY, INC.
EUclid 6-6603
6555 North Ave., Oak Park, Ill.

FILM PRODUCTION EQUIP.
The world's largest source of supply for practically every need for producing, processing, recording and editing motion picture films.
Domestic and Foreign
S.O.S. CINEMA SUPPLY CORP.
Dept. TE, 602 W. 52 St., N.Y.C.-Cable: SOSOUND
Western Branch: 6331 Holly'd Blvd., Holly'd, Cal.

FILM PRODUCTION EQUIPMENT
RENTALS SALES SERVICE
Cameras, Projectors, Recorders
Lighting, Editing, Lab. Equipment
Our Overseas Dept. Equipped for Fast Foreign Delivery
Free Catalogs Available
FLORMAN & BABB
68 West 45th Street New York 36, New York
Cable: FLORBABB, New York MU 2-2928

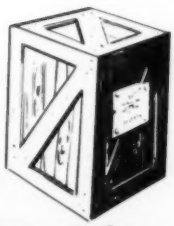
VIDEO FILM LABORATORIES
Complete Laboratory 16MM Service for Producers Using Reversal Process
Also 16MM Negative and Positive Developing
Write for Price List
Video Film Labs are now located at
350 W. 50th St., New York 19. JUdson 6-7196

AURICON CONVERSIONS
400-1200 MAGAZINE OPERATION
The finest job at the lowest price with ball-bearing magazine smoothness built in!
EVERYDAY REVERSAL 16MM PROCESSING
KODAK TRI-X, PLUS-X, DU PONT FILMS
HAROLD'S MOTION PICTURE LABS.
Serving the big upper Midwest in
SIOUX FALLS, S. DAK.

ROCKY MOUNTAIN HEADQUARTERS
For 16mm Film Services
B&W and Anscochrome Processing
Printing—Recording—Editing
Production—Rental—Sales
All types of film in stock
Write for Price List
WESTERN CINE SERVICE, INC.
114 E. 8th Ave., Denver 3, Colo. TAbor 5-2812

Professional cards available to members 12 insertions, 2 x 1 in., $60

COLOR CORPORATION
MOVIELAB BUILDING, 619 W. 54th ST., NEW YORK 19, N. Y., JUDSON 6-0360



new products

(and developments)

Further information about these items can be obtained direct from the addresses given. As in the case of technical papers, the Society is not responsible for manufacturers' statements, and publication of these items does not constitute endorsement of the products or services.

A silicon carbide rectifier has been operated at temperatures up to 1200 F, according to a recent announcement of the General Electric Research Laboratory, Schenectady, N.Y. Similar devices made with semiconductor materials, notably silicon, have been able to operate up to only the 400–500 F range. Basic studies of silicon carbide, a material best known as an abrasive, are part of a GE research program aimed at exploring a variety of compound materials for use in solid-state electronic devices. It was emphasized that the silicon carbide rectifier is still in laboratory development.

An automatic iris and target control unit has been developed by General Precision Laboratory Inc., Pleasantville, N.Y., for use with its industrial and institutional television system. The unit, which weighs 13 lb, can be used with any GPL television system or with any custom system with remote iris operation, can also be used with remotely controlled zoom lenses, and is designed to compensate automatically for wide variations in light — up to 16,000 to 1. It operates from 117 v a-c, 60 cycles/sec.

The ubiquitous eye of the TV camera is now watching New York subway riders for the purpose of catching the larcenous few who sneak under the turnstiles or through the exit gates, thereby defrauding the Transit Authority of rightful revenue. This Orwellish application of closed-circuit television is in operation on an experimental basis at the Independent station at 8th Ave. and 42 St. A small camera installed by General Precision Laboratory Inc., Pleasantville, N.Y., is mounted on a ceiling beam and is focused on the exit gates. Pictures of the area appear on a monitor screen located in a change booth 175 ft from the gates. This experiment is solely for the purpose of apprehending "free-riders," but consideration is being given to the use of television to "police" entire platforms at night and in little used stations as a deterrent to crime.

Multi-Tron Laboratory, Inc., 4624 Washington Blvd., Chicago 44, has announced a new cathode-ray tube called the "Pure Signal" Tube. The tube is described as being of "multiple beam" design and is said to take a signal directly from the crystal detector. Use of the tube is reported to eliminate the necessity for the video amplification circuitry section in any current TV chassis. Pilot model tubes are available to set manufacturers under a licensing agreement.

A newly-designed lens mount is now standard equipment on the latest models of the Oxberry Animation camera, according to a recent announcement by the Animation Equipment Corp., 38 Hudson St., New Rochelle, N.Y. The new lens mount has a ball-bearing, spring-loaded mechanism designed for accuracy and precision. A dial indicator registers actual distance from film plane to lens in thousandths.

FAST!

develops reversal film at 1200 ft. per hr.
negative-positive film at 1200 ft. per hr.

MODEL R-15
REVERSAL FILM
PROCESSOR

- **EXCLUSIVE OVERDRIVE** eliminates film breakage, automatically compensates for elongation; tank footage stays constant.
- **EASY TO OPERATE,** needs no attention.
- **VARIABLE SPEED DRIVE,** development times from 1½ to 12 minutes.
- **COMPLETE DAYLIGHT OPERATION** on all emulsions, no darkroom needed.
- **FEED-IN ELEVATOR & 1200-FT. MAGAZINE** permits uninterrupted processing cycles.
- **STAINLESS STEEL** tanks, air squeegee, recirculation fittings, air agitation tube, lower roller guards.
- **FORCED WARM AIR DRYBOX,** uses no heating lamps.

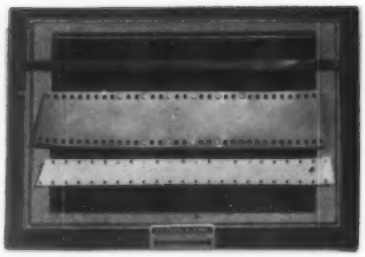
- Double Capacity Spray Wash
- Uniform Tank Sizes
- Cantilever Construction
- Size: 76" x 50" x 24"
- Filtered Air Supply
- Self-Contained Plumbing
- Ball Bearing Gearbox
- Weight: Approx. 475 lbs.

only $2795 F.O.B. Milford, Conn.

LOW COST FINANCE—UP TO 5 YEARS

Machines of Filmline manufacture installed at: Pentagon Bldg., Microfilm division, Washington, D.C.; U.S. Naval Research Laboratory; U.S. Public Health Service; U.S. Treasury Department (15 machines); Atomic Energy Commission; I.B.M.; G.E.; Pratt & Whitney Aircraft; McDonnell Aircraft; Universities of: Texas, Notre Dame, Indiana, California, Alabama, Miami, M.I.T.; TV Stations: WHAS, WMUR, WISH, WBRE, WNCT, WJAR, WTRI, WFMY, WJHP, WCSC, WTVS, WTVJ, KARK, KDUB, WTVR. WRITE FOR DETAILS AND LITERATURE

Filmline corp. Milford, Conn. Dept. JJU-57



A Film Repair and Splicing Block has been announced by Florman & Babb, Inc., 68 W. 45 St., New York 36. It uses Magic Mylar transparent splicing tape to repair badly torn and gouged 35mm slidefilms and 16mm motion-picture films. It is precision machined for accurate registration of 35mm and 16mm film on sprockets as well as for splicing ¼-in. magnetic recording tape. It is priced at $19.95.

A new self-sticking Miniature Marker for identifying small diameter wires, miniature electric components and subminiature circuits is manufactured by the W. H. Brady Co., 727 W. Glendale Ave., Milwaukee 9, Wis. The Markers are designed to stick and stay stuck to any size wire $\frac{5}{32}$ in. and smaller, including plastic coated wires. The $\frac{3}{16} \times \frac{1}{2}$ in. markers are printed in numbers and letters permitting identification of small wires from any angle. The Brady Bulletin No. 130-2 together with usable samples will be sent upon request.

Eastman Kodak Company has placed on the market its fastest photographic film, Kodak Royal-X Pan Film. It is Panchromatic, Type B (high green, low red) and is reported four times faster than Kodak Royal Pan Film when both are given equal development. Ratings as high as ASA 8000 have produced easily printable negatives. Especially designed for press and commercial use where existing light photography is desirable, the film has had extensive pretesting. Enlargements up to five or six diameters do not show excessive graininess. Recommended development is in DK-60a, 6 to 10 min at 68 F. The film requires regular washing procedure. Kodak Royal-X Pan Film is available in 25-sheet packages in commercial sizes up to 8 × 10 in.

A color film said to be 10 times faster than traditional color films is now being marketed by Ansco. Called Super Anscochrome, the new film can be used to make color snapshots by light of an ordinary 40-w fluorescent tube or by the daylight coming through a window. Exposure index is 100 with normal processing, and may be 200 with increased developing time. Basic exposure is 1/500 sec at $f/6.3$. It is possible to use shutter speeds as high as 1/500 to 1/1000 sec, and it is said that color pictures are now possible in extremely unfavorable lighting — even in the rain, if the photographer wishes.

Super Anscochrome is now available in daylight type in 120 size rolls and 35mm magazines for still cameras.

The Genarco Super-Ace, manufactured by Genarco Inc., 97-10 Sutphin Blvd., Jamaica 35, N.Y., is a high-intensity carbon-arc spotlight operating on a-c from a regular 115-v 20-amp line. It is designed particularly for throws over 125 ft. Incorporated in it is the new Genarco Arc Lamp Model AC.3, recently developed for Army searchlights. The light emitted by the double carbon is projected into a 16-in. diameter reflector. Operation can continue for 2½ hr without recarboning. Light output is 14,000 lm. The net weight is 260 lb; total shipping weight is 400 lb.

The SONY C37A, a new high-precision condenser microphone manufactured in Japan by Tokyo Tsushin Kogyo, Ltd., is distributed by Intersearch, 7 Arcadia, Cincinnati 2, Ohio. The microphone uses a titanium diaphragm, specially designed and hand made. Reports on tests in an anechoic sound chamber show the microphone to be flat within ±2 db from 20 to 18,000 cycles. A switch permits the selection of omni- or unidirectional response and three switched low-frequency responses are provided. Output is −70 db. The microphone is priced at $300, including power supply.

Send Your Film To The Complete 16MM Service Laboratory

Unsurpassed for . . .

SPEED — QUALITY — Personalized SERVICE

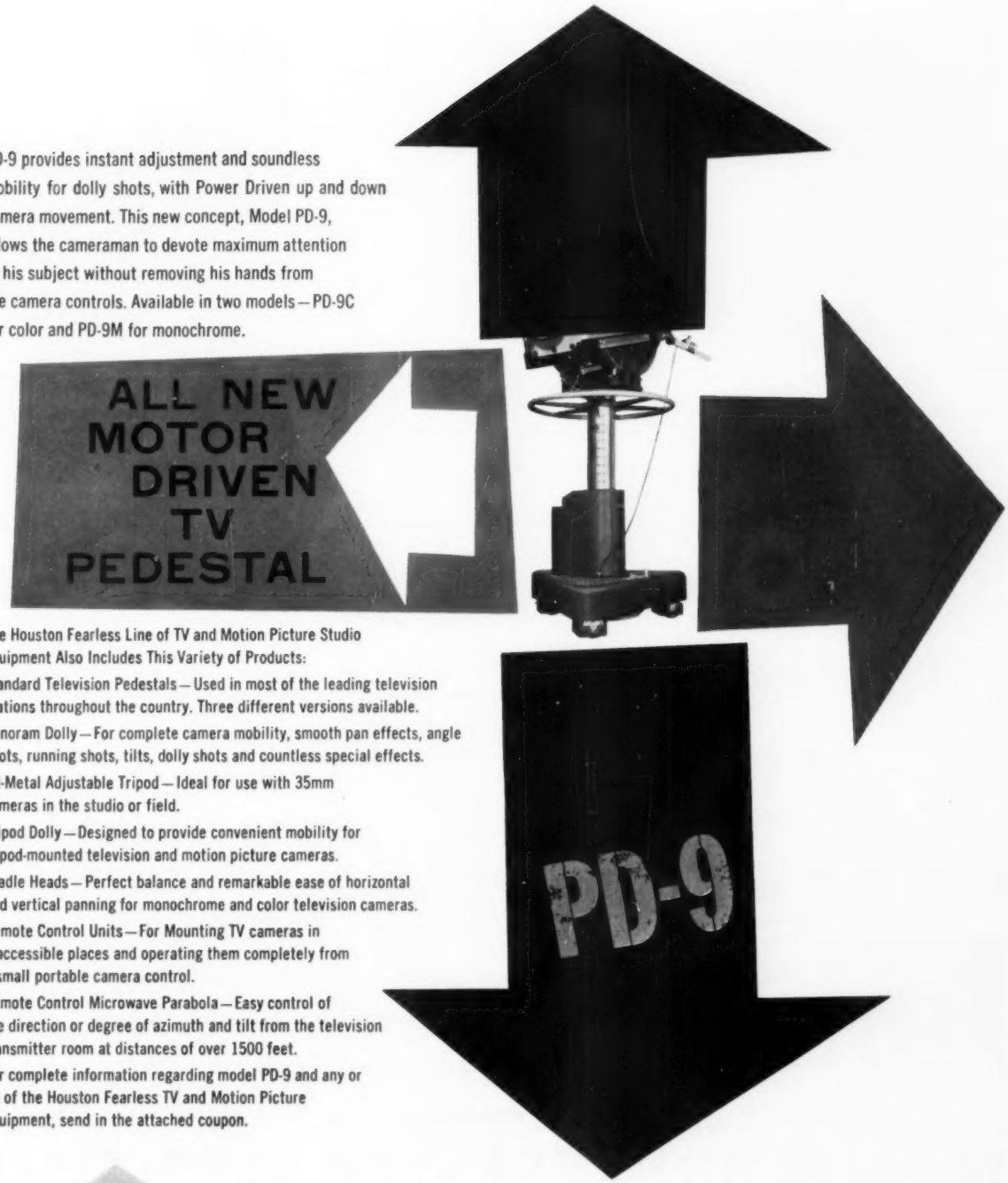
MOTION PICTURE LABORATORIES, INC.

1672 Union Ave., Memphis 4, Tenn., Phone BRoadway 5-2323

MPL®

The Master Craftsmanship Your Film Deserves

PD-9 provides instant adjustment and soundless mobility for dolly shots, with Power Driven up and down camera movement. This new concept, Model PD-9, allows the cameraman to devote maximum attention to his subject without removing his hands from the camera controls. Available in two models—PD-9C for color and PD-9M for monochrome.



The Houston Fearless Line of TV and Motion Picture Studio Equipment Also Includes This Variety of Products:

Standard Television Pedestals—Used in most of the leading television stations throughout the country. Three different versions available.

Panoram Dolly—For complete camera mobility, smooth pan effects, angle shots, running shots, tilts, dolly shots and countless special effects.

All-Metal Adjustable Tripod—Ideal for use with 35mm cameras in the studio or field.

Tripod Dolly—Designed to provide convenient mobility for tripod-mounted television and motion picture cameras.

Cradle Heads—Perfect balance and remarkable ease of horizontal and vertical panning for monochrome and color television cameras.

Remote Control Units—For Mounting TV cameras in inaccessible places and operating them completely from a small portable camera control.

Remote Control Microwave Parabola—Easy control of the direction or degree of azimuth and tilt from the television transmitter room at distances of over 1500 feet.

For complete information regarding model PD-9 and any or all of the Houston Fearless TV and Motion Picture Equipment, send in the attached coupon.

HOUSTON FEARLESS Dept. 00
11801 W. Olympic Blvd Los Angeles 64, Calif.

Please send me complete information on:

☐ PD-9 TV Pedestal
☐ Standard Pedestals
☐ Panoram Dolly
☐ All-Metal Tripod
☐ Cradle Heads
☐ Remote Control Units
☐ Remote Control Microwave Parabola
☐ Tripod Dolly

Name _____
Company _____
Position _____
Address _____
City _____ Zone ____ State _____

The PSC Applied Research Limited Type T246 Mark 3 Automatic Tri-Film Processor is a transportable equipment designed to process and dry automatically 16mm, 35mm and 70mm film. Four lengths of 16mm film or two 35mm lengths can be handled simultaneously, or one 70-mm length. The film magazine holds four 400-ft 16mm films, two 400-ft 35mm films or one 400-ft 70mm film, spooled or on cores. Larger magazines are available.

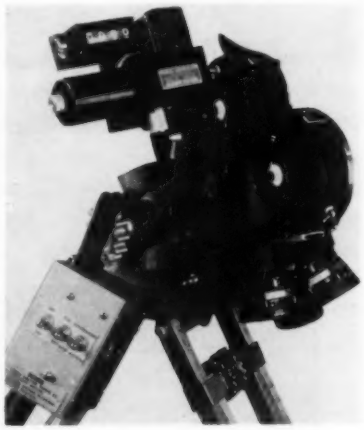
Three basic speeds of 1½, 3 or 6 ft/min can be obtained or changed by a belt adjustment. Further control over processing results from a special programming assembly which can be adjusted to change the loop length in each individual processing tank. No lower rollers are used, as the upper roller system of the equipment automatically forms loops of the correct length in each tank. Processing is controlled by a mechanical program unit after the film is loaded into the machine.

As normally supplied, the first two tanks are used for developing, the second pair for fixing and the last two for washing. Other combinations of tanks and processing solutions, as for stabilization, special hardening or combined development-fixation, may be obtained by changing Saran conductors on the liquid distribution system. Positive-drive pumps with heaters are fitted on two or more of the first four tanks, according to customer requirements. Separate temperature control of the processing solutions is possible on each tank over the range 60 to 110 F, within ±1 F. Temperature control is exercised in the diaphragm heater pumps.

The need for stop baths and interbath rinses is claimed to be virtually eliminated because of a positive squeegee roller design. High temperature chemical resistant plastics and type 316 stainless steel are used in all areas likely to be contaminated by chemicals.

The processor measures 54 in. long, 22 in. wide and 51 in. high, and weighs 400 lb. Power consumption is 5 kva maximum single-phase; 110 v, 45 amp, or according to customer requirements.

This equipment, which is manufactured by PSC Applied Research Ltd., 1500 O'Connor Drive, Toronto, Can., was the subject of a paper presented at the 81st SMPTE Convention in Washington, D.C., which will appear in a forthcoming issue of the *Journal*.



The CECO two-speed, stop motion motor has been announced by Camera Equipment Co., 315 W. 43 St., New York 36, as the smallest and most efficient designed for the Arriflex 16mm Camera and as the first American-made motor available to the camera industry. It provides either ½- or ¼-sec exposure by a knob adjustment. A built-in Veeder Counter is supplied — a one-to-one counter, each digit corresponding to an exposure.

Educators . . .

- Make sure you get the most out of your 16mm sound films
- Use the standard tests your own projector repairman uses
- Measure your projector's performance yourself with the . . .

16mm SOUND-SERVICE TEST FILM

- Points up both projection and sound troubles
- Instruction booklet supplied with the film
- Test instruments are not required. Write . . .

SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS
55 West 42nd Street, New York 36, New York

employment service

These notices are published for the service of the membership and the field. They are inserted three months, at no charge to the member. The Society's address cannot be used for replies.

Positions Wanted

Cameraman. College graduate with B.S. in cinema seeks position as cameraman or assistant cameraman with active motion-picture production group. Presently working with small industrial film outfit as assistant cameraman, film editor and sound recordist. Age 25, married, one child. Resume on request. Write: J. B. E., 139 Constant Ave., Staten Island 14, N. Y.

Motion-Picture and Television Production. Twenty years experience in film and 9 years in television, in all phases of work. Desires position with active organization in motion-picture or television production. Not afraid of hard work, heavy responsibility or any problem that may come up in the industry. Available immediately. Write to: Apartment 601, 137 West 45 St., New York, N.Y., Tel: JUdson 2-2257, Ext. 601.

Motion Picture Photographer. Presently employed with network affiliated television station as news photographer. Organizational ability, experienced in editing, news writing. Present position includes filming commercials and sales presentations, video slides, advertising and promotional stills. Interested in quality creative production. D. David Bash, 724½ Ostend Court, San Diego 8, Calif.

Recording Engineer. Eight years experience in all phases of motion-picture sound recording including operation (as recordist and mixer), research, design and development work, transmission, maintenance and installation. Former assistant to chief recording engineer of major east coast studio. Will relocate. Box 26, Oakland Gardens Station, Flushing, N.Y.

Producer-Director-Cinematographer. Comprehensive background in all phases of motion-picture production: creative, technical and artistic. More than 13 years in motion-picture, live-television and radio production. Independent producer 6 years. Experience also includes writing, editing, acting and narration. Very fluent Spanish including technical terms. Desires position with production company or in motion-picture department of large industrial corporation. Interested in the United States, Central or South America. Résumé available in English or Spanish. Write: Oliver E. Cain, P.O. Box 1594, Amarillo, Texas.

Film Writer-Editor, with directorial experience, now engaged in post-graduate work at City College Institute of Film Techniques. Three years experience in direction of off-Broadway theater. Has written scripts for NBC-TV and industrial films. Experienced with all 16mm cameras and editing equipment. Formerly with Screen Gems, Inc. Willing to relocate. Write: Lawrence G. Cohen, 55 Nagle Ave., New York 40.

Summer Job. Third-year student in Photographic Science, Rochester Inst. of Technology. Secy-Treas. SMPTE Student Chapter. Interested primarily in color control and processing, studied color and black-and-white sensitometry, color printing and color studio, photographic technical analysis. Desires lab work during summer in New York City; available June 3. Write: Stan Feigenbaum, 140 Spring St., Rochester 8, N.Y.

TV Technician. Young man, 27, mechanically inclined, single (but engaged), looking for a TV job with a future. Recent graduate of TV Workshop (finished in top three of class), thoroughly qualified dolly operator, boom operator, audio engineer, TV cameraman, floor manager, video operator, lighting (both as director and grip), and technical direction. Operate film camera and projector and know film processing and editing. Thorough knowledge of remote operations and theory and operation of microwave transmission. Knowledge of color TV principles and operations, scenery and special effects. Intend to secure 1st class license from FCC as radiotelephone operator. Arthur K. Hirshman, 2242 Bragg St., Brooklyn 29, N.Y. NIghtingale 6-3997.

Scientific Film Production. Producer with 12 years experience in production of medical training films and 13 years in still and motion-picture documentation of scientific research material seeks opportunity in studio specializing in scientific, research or educational motion pictures. Four Venice awards, including first prize for best natural science film in 1952. Fellow of the Royal Photographic Society. Wilbour Chace Lown, 306 West 11 St., New York 14. ALgonquin 5-8228.

Positions Available

Motion-Picture Development Engineer. Mechanical engineer or equivalent required by long-established motion-picture developing concern. Must be thoroughly familiar with machine design and construction and capable of supervising projects through manufacturing processes. Technical knowledge of color and spray processes desirable. Salary open. Send resume with references and salary requirements to: Filmline Corp., 43 Erna Ave., Milford, Conn.

Film Inspectors. Permanent or summer positions open. Telephone or write: Kern Moyse, Peerless Film Processing Corp., 165 W. 46 St., New York 36.

Motion-Picture Sound Technicians. US. Naval Photographic Center, Anacostia, D.C., has following three positions open. Interested persons should send their qualifications to the Industrial Relations Officer. **Electronics Technician (Sound), GS-9,** salary $5440 per year. Duties as assistant to Transmission Engineer in the maintenance of motion-picture recording equipment. Applicants must have had at least five years of progressive experience in the production of sound recordings or maintenance of sound equipment, which must include two years of specialized experience in sound recording for motion pictures.

Electronics Technician (Sound), GS-9, salary $5440 per year. Duties as mixer and recordist in motion-picture production. Applicants must have had at least five years of progressive experience in the production of sound recordings or maintenance of sound equipment, which must include two years of specialized experience in sound recording for motion pictures.

Electronics Technician (Sound), GS-7, salary $4525 per year. Duties as recordist in motion-picture production. Applicants must have had at least four years of progressive experience in the production of sound recordings or maintenance of sound equipment, which must include one year of specialized experience in sound recording for motion pictures.

PHOTO PROCESSING TECHNICIANS and MOTION PICTURE CAMERAMEN for permanent work with RCA in FLORIDA

RCA's Missile Test Project at Patrick Air Force Base, Florida, now has openings for experienced processing technicians—still and motion picture (both color and black-and-white). Applicants must have experience in automatic processing techniques. Knowledge of Houston-Fearless equipment highly desirable.

Motion picture cameramen must have extensive background in shooting documentary and technical films. Directing experience desirable.

Continued expansion of our facilities provides an excellent opportunity for those who join our staff *now* to advance to positions of major responsibility.

RCA offers, in addition to liberal salary, such benefits as paid life insurance, cost-free hospital and surgical insurance for employe *and* family, vacations, Tuition Refund Plan, relocation assistance.

For additional information, write for our free brochure:

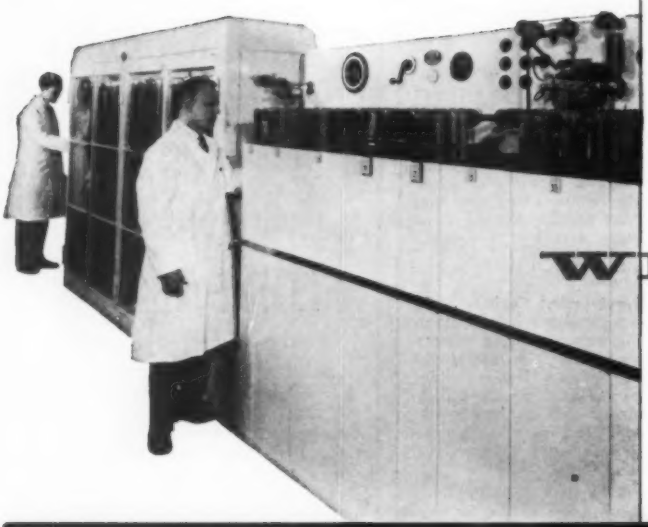
Mr. H. N. Ashby
Employment Mgr., Dept. N-37E
RCA Service Co., Missile Test Project
P.O. Box 1226, Melbourne, Fla.

RCA SERVICE CO., INC.

NOW . . . *16mm Color Prints*

on the New EK Positive Stock

through an **Intermediate Negative Stage**



YOU . . .

shoot on commercial Kodachrome — prepare on A & B rolls — furnish with negative A-wind sound track

WE . . .

make a **color-correct®** *negative incorporating all effects, and 16mm color release prints*

- **LOWER-COST prints**
- **BETTER color**
- **PROTECTS your original footage**
- **COLOR CONTROL complete in one laboratory with a new Arri installation**

For information and price list, write, phone or wire

byron laboratory

1226 Wisconsin Ave., N.W. Washington 7, D.C. FEderal 3-4000

COMPLETE PRODUCER SERVICES . . . COLOR AND BLACK-AND-WHITE PROCESSING AND PRINTING

Contents — pages 364 - 388

News Columns

81st Convention 364
Fall Convention Papers Program 364
From Get-Together Luncheon Speech by Jack Woolley 368
SMPTE Industry Luncheon 370
Exhibits 371
SMPTE Engineering Committee Manual 372
Education, Industry News 374
Obituaries: John A. Norling, Russell O. Drew . . 376
Closed-Circuit TV Communications Progress, by Nathan L. Halpern 378
New Products 383
Employment Service 387

Advertisers

Berndt-Bach, Inc. 373
Byron, Inc. 388
Camera Equipment Co. 370, 371
Camera Mart, Inc. 380
D'Arcy Magnetic Products, Inc. 372
Daven Co. 378
Filmline Corp. 383
Harwald Co. 376
Hollywood Film Co. 365
Houston Fearless 385
Kling Photo Corp. 375
Magnasync Mfg. Co., Ltd. 369
Motion Picture Laboratories, Inc. 384
Movielab Color Corp. 381
Peerless Film Processing Corp. 368
Photo Research Corp. 382
Photo-Sonics, Inc. 379
Precision Film Laboratories, Inc. 366
Prestoseal Mfg. Corp. 367
Professional Services 382
RCA Service Co. 387
Reeves Soundcraft Corp. 377
SMPTE 386
Westrex Corp. 374

Meeting Calendar

American Society for Testing Materials, June 16–21, Chalfonte-Haddon Hall, Atlantic City, N. J.

Professional Group on Electronics, I. R. E., National Convention on Military Electronics, June 17–19, Sheraton-Park Hotel, Washington, D. C.

American Institute of Electrical Engineers, Summer General Meeting, June 24–28, Montreal, Que.

British I. R. E., June 27–July 1, Cambridge University, England.

International Symposium on Physical Problems of Color Television, sponsored by International Union of Pure and Applied Physics, French Physical Society, French Society of Radioelectricians, French Society of Vacuum Engineers, July 2–6, National Conservatory of Arts and Crafts, 292 rue Saint-Martin, Paris 3e, France.

Western Electronic Show and Convention, Aug. 20–23, Cow Palace, San Francisco. The technical program will offer 255 papers at 48 sessions.

Biological Photographic Association, Aug. 27–30, Kahler Hotel, Rochester, Minn.

Illuminating Engineering Society, National Technical Conference, Sept. 9–13, Biltmore Hotel, Atlanta, Ga.

Instrument Society of America, 12th Annual Instrument-Automation Conference and Exhibit, Sept. 9–13, Auditorium, Cleveland, Ohio.

American Statistical Association, Annual Meeting of Section on Physical and Engineering Sciences, Sept. 10–13, Atlantic City, N. J.

American Society of Mechanical Engineers, Fall Meeting, Sept. 23–25, Statler Hotel, Hartford, Conn.

Standards Engineers Society, 6th Annual Convention, Sept. 23–25, Commodore Hotel, New York.

Institute of Radio Engineers and American Institute of Electrical Engineers, Industrial Electronics Conference, Sept. 24–25, Morrison Hotel, Chicago.

82nd Semiannual Convention of the SMPTE, including Equipment Exhibit, Oct. 4–9, Philadelphia-Sheraton, Philadelphia.

National Electronics Conference, Oct. 7–9, Hotel Sherman, Chicago.

American Standards Association, Eighth National Conference on Standards, Nov. 13–15, San Francisco.

83rd Semiannual Convention of the SMPTE, including Equipment Exhibit, April 21–26, 1958, Ambassador Hotel, Los Angeles.

84th Semiannual Convention of the SMPTE, Oct. 20–24, 1958, Sheraton-Cadillac, Detroit.

American Standards Association, Ninth National Conference on Standards, Nov. 18–20, 1958, Hotel Roosevelt, New York.

85th Semiannual Convention of the SMPTE, including International Equipment Exhibit, May 4–8, 1959, Fontainebleau, Miami Beach.

86th Semiannual Convention of the SMPTE, including Equipment Exhibit, Oct. 6–10, 1959, Statler, New York.

SMPTE Officers and Committees: The rosters of the Officers of the Society, its Sections Subsections and Chapters, and of the Committee Chairmen and Members were published in the April 1957 Journal.

sustaining members

of the Society of Motion Picture and Television Engineers

Acme Film Laboratories, Inc.
Alexander Film Co.
Altec Companies
Ampex Corporation
Animation Equipment Corp.
Ansco
C. S. Ashcraft Mfg. Co.
Atlas Film Corporation
Audio Productions, Inc.
The Ballantyne Company
Bausch & Lomb Optical Co.
Bell & Howell Company
Berndt-Bach, Inc.
Bijou Amusement Company
Burnett-Timken Research Laboratory
Byron, Inc.
CBS Television
  Terrytoons, Inc.
The Calvin Company
Capital Film Laboratories, Inc.
Oscar F. Carlson Company
Century Lighting, Inc.
Century Projector Corporation
Cineffects, Inc.
Cinema-Tirage L. Maurice
Geo. W. Colburn Laboratory, Inc.
Comprehensive Service Corporation
Consolidated Film Industries
DeFrenes Company
Andre Debrie Mfg. Corp.
DeLuxe Laboratories, Inc.
Desilu Productions, Inc.
Dominion Sound Equipments Limited
Du Art Laboratories, Inc.
E. I. du Pont de Nemours & Co., Inc.
Dynamic Films, Inc.
Eastman Kodak Company
Elgeet Optical Company, Inc.
Max Factor & Co.
Fordel Films, Inc.
General Electric Company
General Film Laboratories Corporation
General Motors Photographic
General Precision Equipment Corp.
  Ampro Corporation
  Askania Regulator Company
  General Precision Laboratory Incorporated
  The Hertner Electric Company
  International Projector Corporation
  J. E. McAuley Mfg. Co.
  National Theatre Supply
  The Strong Electric Company
W. J. German, Inc.
Guffanti Film Laboratories, Inc.
The Harwald Co.
Hollywood Film Company
Houston Fearless
Hunt's Theatres
Hurley Screen Company, Inc.
JM Developments, Inc.
The Jam Handy Organization, Inc.
Jamieson Film Co.
Kalart Co.
KINTEL (Kay Lab)
Kling Photo Corp. (ARRI Div.)
Kollmorgen Optical Corporation
Lorraine Carbons
J. A. Maurer, Inc.
  Precision Film Laboratories, Inc.
Mecca Film Laboratories, Inc.
Mitchell Camera Corporation
Mole-Richardson Co.
Motiograph, Inc.
Motion Picture Association of America, Inc.
  Allied Artists Products, Inc.
  Columbia Pictures Corporation
  Loew's Inc.
  Paramount Pictures Corporation
  RKO Radio Pictures, Inc.
  Republic Pictures Corp.
  Twentieth Century-Fox Film Corp.
  United Artists Corporation
  Universal Pictures Company, Inc.
  Warner Bros. Pictures, Inc.
Motion Picture Printing Equipment Co.
Movielab Film Laboratories, Inc.
Moviola Manufacturing Co.
National Carbon Company, A Division of Union Carbide and Carbon Corporation
National Screen Service Corporation
Neighborhood Theatre, Inc.
Neumade Products Corp.
Northwest Sound Service, Inc.
Panavision Incorporated
Pathé Laboratories, Inc.
Polaroid Corporation
Producers Service Co.
Projection Optics Co., Inc.
Radiant Manufacturing Corporation
Radio Corporation of America
Reid H. Ray Film Industries, Inc.
Reeves Sound Studios, Inc.
Charles Ross, Inc.
S.O.S. Cinema Supply Corp.
SRT Television Studios
Shelly Films Limited (Canada)
Technicolor Corporation
Titra Film Laboratories, Inc.
Van Praag Productions
Victor Animatograph Corp.
Alexander F. Victor Enterprises, Inc.
Westinghouse Electric Corporation
Westrex Corporation
Wilding Picture Productions, Inc.
Wollensak Optical Company